WATERBIRD AND SHOREBIRD USE OF BEACHES IN BRUNSWICK COUNTY, NORTH CAROLINA

December 2001 - November 2002

Prepared for:

U. S. ARMY CORPS OF ENGINEERS
WILMINGTON DISTRICT
Wilmington, North Carolina

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1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Wilmington District (Corps), has implemented a Wilmington Harbor deepening project that involved the disposal of approximately 5 million cubic yards of sandy dredged material on the beaches of Bald Head Island, Caswell Beach, Oak Island, and Holden Beach in Brunswick County, North Carolina. This disposal occurred over a distance of about 14 miles, during 2001 and 2002. Shorebirds and colonial waterbirds often use beach habitats for nesting, foraging, resting, and roosting. The purpose of this study was to monitor bird use of these beach habitats and collect data to assess the impacts of beach renourishment on these birds. Surveys for this study began in December 2000 and concluded at the end of November 2002. This report summarizes information from surveys between 1 December 2001 and 30 November 2002 (year two) and presents some analyses using all data collected.

1.1 Background Information. In recent years there has been increasing concern on the effects of habitat alteration and disturbance on selected waterbird groups. One of the most important factors to colonial nesting waterbirds is the availability of suitable, undisturbed nesting habitat. Many colonial nesting waterbirds (primarily pelicans, gulls, terns, and the black skimmer) in North Carolina that once were dependent on nesting sites in association with ephemeral beach and inlet habitats are now dependent on selected dredged-material sites (Parnell and Soots 1975, Parnell and Shields 1990). The concentration of more birds nesting at fewer sites has increased the risk of catastrophic nesting failures. Human activities and predatory species present an increasing source of disturbance for nesting, feeding, and resting birds in all coastal habitats.

Shorebirds (primarily sandpipers, plovers, willet, turnstones, and oyster catchers) represent another group of waterbirds that has been the subject of recent concern and studies. Some shorebird species spend up to two-thirds of the year in migration and on wintering grounds (Burger 1984). Most shorebirds migrate between the Arctic tundra breeding grounds and South American wintering grounds. Recent studies have documented the importance of staging areas for these long-distance migrants (Myers et al. 1987, Clark et al. 1993, Hicklin 1987, Dodd and Spinks 2001). Many shorebirds take advantage of seasonally abundant food resources at these intermediate staging areas along their annual migratory cycle.

There is relatively little information on the effects of beach renourishment on bird populations. There has been one study in the general vicinity of the study area that includes a characterization of beach use by birds in three 1.5 km transects in New

Hanover County (Smith 1988). Information on seasonal numbers and distribution of shorebirds on North Carolina's Outer Banks is available from over 123 km surveyed in 1992 and 1993 (Dinsmore et al. 1998). Abundance information is available on shorebird populations in Virginia (Watts and Truitt 2000) and South Carolina (Dodd and Spinks 2001). Most studies have concentrated on seasonal abundance, habitat use and identifying important staging areas. No detailed, comprehensive studies or data are available for bird use of beaches in Brunswick County, North Carolina.

2.0 STUDY AREA

Eleven transects were surveyed under the USACE Delivery Order for this portion of the study. Three transects were located on Bald Head Island, four on Oak Island, and four on Holden Beach. Two additional transects were surveyed with the same protocol at Ocean Isle Beach under a separate USACE Delivery Order. Detailed results and information from these two transects are found in a separate report, but some data from these sites are discussed herein in comparison to data from this study.

Transects covered all habitats from the primary dune to the intertidal/surf habitat. Transects were established to represent all habitat types in the study area and varied in length because an effort was made to cover all potentially suitable nesting habitats, especially in the vicinity of inlets. Transect lengths ranged from 1.6 km (1 mile) to 3.2 km (1.75 miles). The cumulative length of these eleven transects was 22.4 km (13.75 miles). Transects were referenced with sequential numbers (i.e., transects 1 through 11) from east to west (Figures 1 through 4). A summary of transect locations, features, and characteristics is found in Table 1. Coordinates along each transect were determined using a sub-meter accuracy global positioning system (GPS) and are referenced with visual features in Appendix A.

3.0 METHODS

3.1 Survey Seasons and Zones. Transects were identified as those subject to year-round surveys or those subject to non-breeding season surveys (Table 1). Five transects (1, 3, 7, 8, and 11) were surveyed year-round, because they contain potential nesting habitat. Six transects (2, 4, 5, 6, 9, and 10) were surveyed during the non-breeding season. All transects were surveyed with the same frequency during the non-breeding season. Six additional surveys were conducted during the breeding season for the five year-round transects.

Surveys during the non-breeding season were conducted at different frequencies, based on known seasonal abundances of waterbirds and shorebirds in the region. Surveys were conducted weekly during migration (15 July to 30 November

and 15 February to 30 May) and every other week during the mid-winter period (1 December to 15 February). Weekly surveys for breeding birds were conducted from 1 March through 15 July for the year-round transects. Since the breeding survey period overlaps the migration periods, surveys for both breeding and non-breeding use were combined for these periods of overlapping coverage.

Each transect was divided into three zones of microhabitat (intertidal/surf, beach, and dune areas), and four equally spaced zones along the longitudinal axis of the transects, represented as East, East-middle, West-middle, and West on the data sheet. Bird species and numbers were recorded in these zones along with the bird's activity (i.e., feeding, resting, flying, or breeding). Beach was defined as the area from the normal high water/tide (often denoted with the presence of a berm) to the toe of the primary dune. Overwash areas were included within the beach microhabitat. Any disturbances (e.g., people, pets, dredging, and predators) were also recorded.

3.2 Survey Procedures. The duration of each survey varied among transects and within transects depending on the amount and type of habitat covered, and the number of birds present. All habitats including dunes, beach, and intertidal zones were surveyed in each transect. This was accomplished by walking parallel to the beach in most areas, but also required walking paths that zig-zagged across wider habitats. Transects were surveyed slowly and thoroughly to allow detection of all individuals of all species present and to insure that large mixed flocks of birds were thoroughly searched to locate, identify, and count all individuals of all species. Because all individuals were counted, the level of effort per km surveyed was considered equal for all transects.

Surveys were conducted during daylight hours between 30 minutes after sunrise to 30 minutes before sunset. Surveys were not conducted during poor weather conditions (heavy wind >25 mph, heavy rains, severe cold). Weather conditions including clouds, wind speed, wind direction, air temperature, and water temperature were recorded for each survey. Wind speed and air temperature were calculated using a Brunton Windwatch and wind direction was determined using a compass. Surf water temperatures were obtained from the *Wilmington Morning Star* newspaper. Tide times were recorded for each survey and were obtained from NOAA, National Service tide tables and corrected to the closest location where tidal correction times were provided. Each survey was categorized into one of two tidal categories (low or high) based on the time of the survey and the time to the closest low or high tide. Therefore, those surveys within $3\pm$ hours of high tide were classified as occurring at high tide. If a survey period included time from both categories, the survey was recorded in the category where more time was spent. This information along with the date, times of surveys, and location of each observation was recorded on a daily field data sheet.

Additional data on nesting species were recorded during the breeding season. These data included nesting chronology (e.g., dates when birds were first seen on the site, nest establishment dates, dates when unfledged chicks are present on the site), locations of the nests using GPS technology, locations of brood foraging territories for shorebirds, and known or suspected causes of nest and chick loss (e.g., pets, predators, and humans). Particular attention was concentrated in the vicinity of inlets, which typically provide the best nesting habitat for shorebirds and colonial waterbirds. Potentially nesting plovers were watched with care, and suitable nesting habitat for plovers was thoroughly searched for any isolated nests. All sightings of piping plovers were reported to the USACE, U.S. Fish and Wildlife Service (USFWS), and N.C. Wildlife Resources Commission (NCWRC).

3.3 Statistical Analysis. Monthly differences in abundance (number of individuals) and species richness (number of species) were examined using a single factor repeated measures analysis of variance (ANOVA) on monthly transect means. If a significant month effect was found ($\propto = 0.05$), a Student-Newman-Keuls multiple comparison procedure was performed to determine which months were significantly different. Data were analyzed using SigmaStat Version 2.0.3 (SPSS Incorporated, Chicago, IL).

Also of interest was the effect of tide on abundance and richness. To test whether tide was a significant factor in either parameter, mean high tide and low tide abundance and richness were calculated for each transect. The means were then analyzed for significant differences using a t-test, or, when appropriate, a Wilcoxon Rank Sum test.

The possible effects of renourishment could differ for shorebird and waterbird species, therefore individuals were classified as waterbirds or shorebirds and analyzed separately. Also, sand was applied to the transects at different times of the year resulting in different pre- and post-nourishment dates for each transect. This necessitated that each renourished transect be compared to the control transect separately. In order to ensure spatially independent sampling, the control transect was located as far as possible from the renourished transects of interest.

Richness and abundance data were analyzed as a Before-After/Control-Impact design (BACI) study (Stewart-Oaten and Murdock 1986, Schroeter et al. 1993). Species richness and abundance for waterbirds and shorebirds at Control and renourished transects were monitored during the pre- and post-nourishment period (henceforth designated as Before and After, respectively). Then, for each sampling date, the difference between the renourished and control transect for the parameter (*e.g.* abundance) of interest ($\triangle$) was calculated. The control value was always subtracted from the renourished transect value, therefore, a negative $\triangle$ indicates that, for that sampling date, the parameter of interest was higher at the control site. The

mean $\triangle$s of the Before ($\triangle_b$) and After ($\triangle_a$) periods were then compared using a t-test, or, when appropriate, a Wilcoxon Rank Sum test. This method controls for seasonal variability and takes into account pre-existing differences in control and renourished areas; therefore, any significant differences between $\triangle_b$ and $\triangle_a$ can presumably be attributed to renourishment activity. Using this method renourished beach transects (2, 5, 6, and 9) were compared with the unrenourished/control beach (Transect 10).

Due to the inter-specific and intra- specific variability in abundance and richness data, it was possible that the effects of beach replenishment on individual species could go undetected. Therefore, the effects of beach renourishment on individual species of waterbird and shorebird were also examined using the BACI method. Although shorebirds were expected to be most susceptible to renourishment impacts, to be comprehensive, several waterbird species were chosen for analysis as well. The individual waterbirds chosen were those that were most abundant and present year-around in the survey areas. Only the most abundant shorebird species were used, as other shorebird species were recorded too infrequently to allow adequate statistical analysis. Specifically, four waterbird species, brown pelicans, laughing gulls, ring-billed gulls, and royal terns, and four shorebird species, willet, sanderling, black-bellied plover, and ruddy turnstone were used.

The BACI method required that certain assumptions be met. First, the $\triangle$s from the before period must be additive. This means that, 1) $\triangle_b$ had no relationship to sampling week , and 2) $\triangle_b$ did not vary with the parameter of interest (e.g., $\triangle_b$ does not increase with abundance). Second, $\triangle_b$ and $\triangle_a$ must be normally distributed and have equal variance. The normality and equal variance assumptions were checked using the Kolmogorov-Smirnov test and Levene median test, respectively. If the normality or equal variance assumptions were not met, the data were log transformed or a non-parametric Wilcoxon rank sum test was used. The additivity assumptions were checked by linear regression ($\propto = 0.05$). If the second assumption was not met the data were log $(x + 0.1)$ transformed. If the second assumption was not met after transformation no test was performed. Failure of the first additivity test indicated that a trend in the $\triangle$s existed in the pre-nourishment data; consequently, any trends in the post nourishment data could not be unambiguously attributed to the renourishment. In such a case no statistical analysis was performed. Finally, the power of each test was calculated. Power refers to the probability that a statistical test will detect a treatment effect if an effect is actually present. The ability of the statistical test to detect treatment effects increases as power moves toward one. Power generally increases with sample size and decreases with variability.

Also tested was the interaction of habitat use, beach renourishment, and tidal stage. Tidal preference, as shown by relative abundance at high and low tide, was compared before and after renourishment using total waterbirds and shorebirds, as well as several individual species. Comparisons were made using a two-way ANOVA

with renourishment period (before and after renourishment) and tidal stage (high and low) as factors. A significant ($\propto = 0.05$) interaction between renourishment period and tidal stage was considered evidence for an effect of renourishment on tidal habitat use.

Beach renourishment has the potential to influence bird behavior in several ways. For example, renourishment entails substantive changes in beach morphology that may affect changes in flying or resting behaviors at renourished transects. Similarly, some researchers have found that beach renourishment disturbs benthic macroinvertebrate communities (Rakocinski et al, 1996), and such a disturbance could alter feeding behavior in bird species whose diet relies on benthic organisms. Finally, behavioral changes related to beach renourishment could be important in explaining any renourishment effects on species richness and abundance. Therefore, for each survey week the percentage of birds engaged in feeding, resting and flying behaviors was calculated. Each behavioral category was then compared before and after beach renourishment using t-tests; behavioral data collected at the control transect were processed in the same manner. The behavior of shorebirds and waterbirds was examined separately. In addition, selected species were chosen for analysis based on the likelihood of being affected by renourishment. Only a few shorebird species were observed frequently enough to permit analysis.

4.0 RESULTS AND DISCUSSION

4.1 Waterbird Species Richness. A summary of survey dates and corresponding survey week for all transects is found in Appendix B. Completed data sheets from each survey are found in Appendix C. Forty-three waterbird species were recorded from transects during the survey period (Table 2). Cumulative waterbird species richness was highest (29) on Transect 11 (Holden Beach, Shallotte Inlet) and lowest (15) on Transect 6 (Oak Island, West Beach). The total numbers of waterbird species recorded per survey by transect are found in Appendix D. Monthly waterbird species richness (presented as species/km/survey) for the first and second year of monitoring can be found in Figure 5. Overall, richness exhibited similar monthly trends in both years of monitoring. Mean monthly waterbird species richness was lowest during January and February and was highest in spring and fall.

Table 3 and Figure 6 present waterbird species richness by beach, inlet, and cape transects. Patterns of species distribution in 2001 and 2002 were similar, with the greatest richness found at the cape transect. The beach and inlet transects had similar species richness.

4.2 Waterbird Abundance. Waterbirds were most abundant at Transect 5 (Oak Island, Beach) and Transect 6 (Oak Island, Beach) with 165.4 birds/km and 157.9

birds/km, respectively. Waterbirds were least abundant at Transect 2 (Baldhead Island, Beach) with 34.3 birds/km. Waterbird abundance (birds/km/survey) is found in Table 3 in each cape, beach, and inlet categories. Numbers of waterbirds peaked for the year during fall migration in October and November (Figure 7). Waterbird numbers were lowest in February and May. The total numbers of individuals recorded per survey by transect are found in Appendix E. During the two year monitoring period, mean monthly waterbird abundance (birds/km) was highest in October and November and lowest in February, May, and August (Figure 7).

Figure 8 presents waterbird abundance by beach, inlet, and cape transects. Patterns of abundance in 2001 and 2002 were similar. Waterbird abundance was greatest at the cape transect followed by the beach transects. Mean waterbird abundance was lowest at the inlet transects during both survey years.

The five most abundant waterbird species recorded were the Laughing Gull (*Larus atricilla*), Ring-billed Gull (*Larus delawarensis*), Brown Pelican (*Pelecanus occidentalis*), Royal Tern (*Sterna maxima*), and the Herring Gull (*Larus argentatus*) (Table 4). Although all of these species are present in the study area in some numbers throughout the year, the Ring-billed Gull and Herring Gull are more common winter residents and the Laughing Gull is a much more common summer resident. Abundance by transect of each waterbird species recorded can be found in Appendix F.

4.3 Shorebird Species Richness. Twenty-three shorebird species were recorded from the transects during the survey period (Table 5). Cumulative shorebird species richness was highest (20) at Transect 7 (Oak Island, Inlet) and lowest (7) on Transects 2 (Bald Head, South Beach) 6 (Oak Island, Beach), and 9 (Holden Beach, Beach). The total numbers of shorebird species recorded by transect are found in Appendix G. Monthly trends in species richness were similar in both monitoring years. Mean monthly species richness was lowest in January, February, and June and highest in May and in the fall months (Figure 9).

Table 6 presents shorebird species richness by beach, inlet, and cape transects. Abundance was similar at all transect types, though mean richness was somewhat lower at beach transects compared to cape and inlet transects during 2001 and 2002.

4.4 Shorebird Abundance. Shorebirds were most abundant at Transect 7 (Oak Island, Inlet) with 63.4 birds/km/survey and least abundant at Transects 6 (Oak Island Beach) and 9 (Holden Beach, Beach) which had 10.6 birds/km. The most abundant shorebirds (birds/km/survey) are found in Table 7 for each cape, beach, and inlet categories. Numbers of shorebirds peaked during spring migration in February and March and during the fall migration, September through November (Figure 10). Shorebird numbers were lowest in December, January, June, and July. The total

numbers of individuals recorded per survey by transect are found in Appendix H. Mean monthly abundance (presented as birds/km) for shorebirds can be found in Figure 10. Shorebird abundance was much higher during February and March of 2002 compared to the same time in 2001. Otherwise, trends were similar in both study years, with the greatest abundance of shorebirds occurring during November and lowest during December, January, June, and July.

Figure 8 presents shorebird abundance by beach, inlet, and cape transects. Abundance was highest at inlet transects in 2001 and 2002, while shorebird abundance at the cape and beach transects was similar during the same period. The overall pattern of shorebird abundance at cape, beach, and inlet transects was similar during 2001 and 2002.

The five most abundant shorebird species recorded were the Sanderling (*Calidris alba*), Willet (*Catoptrophorus semipalmatus*), Dunlin (*Calidris alpina*), Short-billed Dowitcher (*Limnodromus griseus*), and Black-bellied Plover (*Plavialis squatarola*) (Table 7). Only one of the five most abundant shorebird species, the Willet, breeds in North Carolina. The remaining four species breed in tundra habitat in the far north and occur in North Carolina as migrants or winter residents. Abundance by transect of each shorebird species recorded can be found in Appendix I.

4.5 Habitat Use. More waterbirds and shorebirds were recorded in the intertidal/surf zone compared to beach and dune habitats. Habitat use by waterbirds in each of the three zones, with corresponding percent of total recorded, was intertidal/surf with 72 percent, beach with 18 percent, and dune with 10 percent. Habitat use by shorebirds in each of the three zones, with corresponding percent of total recorded, was intertidal/surf with 86 percent, beach with 13 percent, and dune with 1 percent.

When considering the geographic position of the transects and evaluating habitat use in the categories of beach, inlet, and cape, waterbird activity was highest in the intertidal zone of all three categories. Nearly 80 percent of all waterbird observations at the cape and inlet transects were recorded in the intertidal zone (Table 8). The highest percentage of beach use for waterbirds was recorded in beach transects and for shorebirds were recorded at inlet transects. At the cape transect, 95 percent of all shorebird observations were recorded in the intertidal zone (Table 9). It should be noted that habitat preference cannot be inferred since habitat use was not compared to habitat availability.

4.6 Activity. Approximately 8 percent of all waterbird observations were associated with feeding birds, 41 percent with flying/migrating birds, 51 percent resting birds, and none with breeding activity (Table 10). Resting activity for waterbirds was highest (55.9 percent) at the cape transect and lowest (41.6 percent)

at beach transects. Feeding activity was relatively low (less than 12 percent) for waterbirds at all transects.

Approximately 58 percent of all shorebird observations were associated with feeding birds, 28 percent with resting birds, 14 percent with flying/migrating birds, and less than one percent with breeding activity (Table 11). Resting activity for shorebirds was highest (57.7 percent) at inlet transects and lowest (11.3 percent) at the cape transect. Feeding activity for shorebirds was highest (69.8 percent) at beach transects and lowest (28.6 percent) at inlet transects.

4.7 Nesting Birds. Signs of nesting were observed for Wilson's Plover (*Charadrius wilsonia*) and Killdeer (*Charadrius vociferus*) during the 2002 breeding season (Table 12). Two additional shorebird species, American Oystercatcher (*Haematopus palliatus*) and Willet (*Catoptrophorus semipalmatus*), probably nested in the vicinity. American Oystercatcher was documented nesting at Shallotte Inlet on Ocean Isle Beach. Four pair of Wilson's Plovers were suspected of nesting in the vicinity of inlets. Several pairs of Willets were found in the vicinity of Shallotte Inlet and in the marsh, outside the study area of Transects 7 and 11.

Four Wilson's Plover nests resulted in the production of at least six young. No Least Terns (*Sterna antillarum*) nested along the beaches during 2002. Although Willets were suspected of nesting in the soundside marsh, no nests, or young were found. Summary notes on nesting chronology on nesting and suspected nesting species are presented in Appendix J.

4.8 Observations of Disturbance. Fewest people per survey (4.8) were found on Transect 4, at Caswell, and the most (71.6) were encountered at Transect 9, Holden Beach, and East Beach (Table 13). Average number of people encountered per survey was 16.1 at the cape transect, 27.3 at inlet transects, and 48.3 at beach transects. Number of people encountered per survey by island averaged 15.7 at Bald Head Island, 34.18 on Oak Island, and 52.6 on Holden Beach. Most of the surveys recorded a disturbance from humans. Of these disturbances 20 percent contained a disturbance with a dog. No disturbance from predators was noted, although gulls and hawks, which often prey on other birds, young, or eggs, were documented. The presence of dog, raccoon (*Procyon lotor*), fox, and human tracks were relatively common in the vicinity of all attempted nesting locations.

4.9 Effects of tide. Mean 2002 waterbird abundance and species richness relative to low and high tide surveys are presented in Tables 14 and 15. Mean 2002 shorebird abundance and species richness are presented relative to low and high tide surveys in Tables 16 and 17. Abundance of waterbirds was greater at high tide for all transects except Transects 8 and 9, with significant differences in abundance found for Transects 1 ($p = 0.002$), 3 ($p = 0.006$), and 4 ($p = 0.026$). Waterbird richness was generally similar at high and low tide, though waterbird richness was significantly higher at high tide at Transects 1 and 3. The data do not suggest that the effect of tide on waterbird richness and abundance differed between cape, inlet, and beach

sites. However, for shorebirds, tidal effects did seem to be greater at inlet transects. Shorebird abundance was significantly higher at all inlet transects except Transect 7, while, of the beach transects, only Transect 10 ($p = 0.031$) had significantly greater numbers of shorebirds at high tide. Shorebird richness was higher, on average, at inlet transects during high tide, however, significant differences in species richness were found only at inlet Transects 4 ($p = 0.025$) and 11 ($p < 0.001$). Species richness at beach transects was similar at high and low tide except for Transects 6 and 10 which had significantly greater species richness during low and high tide surveys, respectively.

4.10 Effects of Beach Renourishment on Waterbirds. Abundance (birds/km of transect) and richness (species/km of transect) for renourished transects and the control are presented in Appendix K. The results of the t-test comparisons are shown in Tables 18 and 19.

Waterbird abundance did not appear to be altered by beach renourishment. T-tests revealed no significant differences in the Δ_b and Δ_a for waterbird abundance at any renourished transect. Before period non-additivity was present at Transects 5 and 6; therefore, no tests were performed. For both transects, the Δ_a was much greater than Δ_b, indicating that, on average, relative abundance increased at the renourished transects after the renourishment period. However, a week to week comparison of sampling dates indicates that the relationship of control abundance and abundance at Transects 5 and 6 was similar in the before and after period for most survey weeks and that the greater mean number of birds at the treated transects after renourishment may have been due to a few weeks in which abundance at the renourished transects was exceptionally high (Appendix K, pages K-4 and K-5). Similarly, relative abundance at Transect 2 and the control was seasonally similar before and after renourishment (Appendix K, page K-2).

The effect, if any, of beach renourishment on waterbird species richness is difficult to determine. The Δ_a for species richness was higher than Δ_b at Transects 2, 5, and 6, although the difference was only significant for Transects 5 ($p = 0.020$) and 6 ($p = 0.014$). The opposite effect was found for Transect 9, in which the mean delta was lower in the after period ($p < 0.001$), indicating that, after renourishment, Transect 9 experienced a decline in richness relative to the control transect. Furthermore, the lower Δ_a was not the result of a few abnormal survey weeks, as Appendix K page K-7 indicates that richness was consistently lower at Transect 9 compared to the control during the post nourishment period. In interpreting the results it should be noted that the mean difference pre- and post renourishment species richness was less than one bird/km/survey for most transects. Consequently, any re-nourishment effect, whether adverse or beneficial, seemed to be minor.

Laughing gull abundance showed patterns similar to those of waterbirds as a

whole, likely due to the fact that laughing gulls comprised a large portion of total waterbird records. All transects, except Transect 2, had a higher delta value in the post-nourishment period compared to the pre-nourishment period (Table 20). The Δ_a was significantly greater than Δ_b at Transects 5 ($p = 0.040$) and 9 ($p = 0.018$). As with waterbirds considered as a whole, the post-nourishment deltas were highly variable and do not strongly indicate that beach nourishment consistently increased abundance at renourished transects relative to the control. For most transects, except for occasional spikes in abundance at the renourished sites, control and renourished transects track well throughout the two survey years Appendix K, pages K-9 through K-12.

Royal tern abundance did not appear to be altered by beach renourishment. The mean Δ_a value was greater than Δ_b at all transects (Table 21). However, the difference was not significant at Transects 5 and 9. Also, the relationship of royal tern numbers at control and renourished transects 5, 6, and 9 was not consistent throughout the post-nourishment monitoring period (Appendix K, pages K-14 through K-16). The inconsistency may have resulted from natural variability or temporal changes in the effects of renourishment. Delta values at Transect 2 were significantly ($p = 0.042$) and consistently higher after renourishment. However, because royal terns were present only seasonally, there were only eight weeks of pre-nourishment surveys in which royal terns were present; therefore, no strong conclusions could be made using data from Transect 2.

Aside from a few spikes in abundance, brown pelican numbers were temporally similar to the control before and after renourishment (Table 22, Appendix K, pages K-17 through K-20). Relative abundance at the renourished transects was higher after renourishment, however the differences were not significant.

No tests were performed on ring-billed gull abundance at Transects 2, 5, and 6 (Table 23, Appendix K, pages K-21 through K23). Transects 5 and 6 displayed a significant downward trend in Δ_b values which precluded further testing. Transect 2 was not tested because of a failure of the second additivity assumption (i.e., Δ_b was related to abundance). It is likely that Transect 2 failed the additivity test because of high variability of ring-billed gull numbers at the control transect. Transect 9 had a significantly greater Δ_b value. Weekly survey data also suggest that Transect 9 had consistently higher gull numbers after renourishment (Appendix K, page K-24). However, because similar results were not evident at the other renourished transects, it is not possible to attribute the results found at Transect 9 to beach renourishment.

Beach renourishment could have exerted short-term effects which were difficult to evaluate using all survey weeks. Therefore, using only the weeks immediately following renourishment, weekly survey data for total waterbirds and selected individuals were evaluated. Weekly trends did not reveal any consistent short-term

changes in abundance or richness.

Beach renourishment did not appear to exert an effect on tidal habitat use by waterbirds. No significant interaction between renourishment and abundance at high and low tide was found at any transect (Table 24). Nor was a significant interaction found for the two waterbird species, laughing gull and royal tern (Table 25). Theoretically, waterbirds tidal preference could be altered by renourishment, as far more beach would be available at high tide after renourishment compared to before renourishment. However, no such renourishment effect was found in this study.

Waterbird activity in the pre- and post-nourishment period is presented in Figures 11-14. At all renourished transects, a greater percentage of waterbirds exhibited resting behavior after renourishment compared to the pre-nourishment period, with significant differences at Transects 2 ($p < 0.001$) and 9 ($p = 0.039$). The percentage of birds recorded moving over the renourished transects declined after renourishment at Transects 2 ($p = 0.042$) and 9 ($p = 0.032$). The control transect displayed similar behavior during the same time period, but no significant differences in pre- and post-nourishment resting were detected. To further examine patterns in resting and moving behavior, laughing gulls and royal terns were considered individually. Both species showed pre- and post-nourishment behavioral patterns similar to overall waterbird behavior (Appendix L, pages L-1 through L-7). Resting behavior increased, while the percentage of birds recorded flying declined at most transects during the post-nourishment surveys. A significantly greater post-nourishment percentage of resting birds was found at Transects 2 ($p = 0.007$) and 5 ($p < 0.001$) for laughing gulls and at Transects 5 ($p = 0.036$) and 6 ($p = 0.016$) for royal terns. The percentage of birds flying was significantly lower after renourishment at Transects 5 ($p = 0.002$) and 6 ($p = 0.027$) for laughing gull and Transect 6 ($p = 0.012$) for royal terns. However, it should be noted that royal terns at the control transect displayed temporal patterns of moving and resting behavior similar to that found at the renourished transects. The greater resting time was primarily at the expense of flying behavior, as total waterbird, laughing gull and royal tern feeding behavior did not significantly differ before and after renourishment at any transect.

The behavioral data suggest that waterbirds increased the percentage of their time spent resting after beach renourishment. One possible explanation is the larger available beach space. Before renourishment, much of the beach was intertidal, and little resting area was present at high tide. Under such conditions, resting space was limited and, at high tide, waterbirds present at the transect would be expected to spend more time feeding and flying. Upon renourishment, resting could occur at any tidal stage, and, consequently, more birds were observed resting in the post-renourishment surveys. Why flying and not feeding behavior declined is uncertain. Although fish constitute much of the waterbird diet, benthic organisms represent a significant component as well, and changes in invertebrate community structure would

likely manifest in the behavior of their avian predators. However, despite the impacts of renourishment on benthic communities found in the study area (Versar, Inc. 2002), those impacts were not reflected in waterbird feeding behavior. Although birds were recorded as feeding, the success of foraging birds remains unknown.

4.11 Effects of Beach Renourishment on Shorebirds. Abundance (birds/km of transect) and richness (species/km of transect) for renourished transects and their respective controls are presented in Appendix M. The results of the t-test comparisons are shown in Tables 26 and 27.

Shorebird abundance at the control site was highly variable throughout the monitoring period. This lack of consistency in the relationship of the control transect to Transects 2 and 5 led to a violation of the additivity assumption; consequently, no t-test comparisons were made for Transects 2 and 5. At both transects, Δ_a was higher than Δ_b (Table 26). However, no renourishment effect was evident, at either transect, in weekly survey data (Appendix M, pages M-3 and M-4). Similar results were found for Transects 6 and 9.

Beach renourishment had no effect on shorebird richness. The Δ_a for shorebird richness was not significantly different than Δ_b at Transects 2, 5, and 6 ($p = 0.254$, $p = 0.445$, $p = 0.624$, respectively; Table 27). However, Δ_a was significantly lower than Δ_b at Transect 9 ($p = 0.029$). The reason for the relative decline in species richness at Transect 9 may have been due to the high variability in shorebird richness at the control transect (Appendix M, page M-7).

For willet numbers alone, no significant differences in Δ_b and Δ_a were found for Transects 2 and 9 (Table 28), and no tests were performed on Transects 5 and 6 due to violations of additivity. Though renourishment did not appear to alter willet abundance it should be noted that the delta values were highly variable in both the before and after period, which made any renourishment effects difficult to discern (Appendix M, pages M-9 through M-12).

Renourishment did not appear to affect abundance of sanderlings (Table 29). Delta values for sanderling abundance were not found to differ in the pre- and post-nourishment period. Also, no renourishment effects were visible in Appendix M, pages M-13 through M-16; the relationship of the renourished transects to the control appears similar during the pre- and post-nourishment periods.

BACI analysis did not reveal any renourishment effects on Black-bellied plovers or ruddy turnstones (Table 30 and 31; Appendix M, pages M-17 through M-24). However, both species showed strong seasonal patterns in visitation and, for a large number of surveys, neither species was observed at the control or treatment transects, which greatly limited power of statistical tests.

Beach renourishment could have exerted short-term effects which were difficult to evaluate using all survey weeks. Therefore, using only the weeks immediately following renourishment, weekly survey data for total shorebirds and selected individuals were evaluated. Weekly trends did not reveal any consistent short-term changes in abundance or richness.

Beach renourishment did not appear to exert an effect on tidal habitat use by shorebirds. No significant interaction between renourishment and abundance at high and low tide was found at any transect (Table 24). Nor was a significant interaction found for willets at any of the renourished transects (Table 32). Renourishment did significantly affect tidal habitat preference of sanderling at Transect 5, but no renourishment effect was evident for this species at the other transects (Table 32). Although renourishment could alter tidal preference in shorebirds by changing the amount of beach available at various tidal stages, tidal preference appears to exist only at inlet transects (Table 16); therefore, the effects of renourishment at beaches is likely minimal.

As with waterbirds, shorebird resting behavior seems to have been most affected by beach renourishment (Figure 15-18). The percentage of resting birds was significantly higher in the post-nourishment period at Transects 2 ($p = 0.005$), 5 ($p = 0.002$), and 6 ($p = 0.015$). At the same transects, a non-significant decline in the percentage of flying and feeding shorebirds occurred during the post-nourishment period, but a similar drop in feeding behavior occurred at the control transect during the same time. When willets alone were considered, their resting behavior was temporally similar to that of shorebirds as an aggregate, but statistically significant differences in willet resting activity before and after renourishment were not present at any transect (Appendix L, pages L-8 through L-11). Willet feeding behavior also decreased after renourishment; however, feeding at the control transect declined in the same manner. Like willets, sanderling spent most of their time feeding. This was true before and after beach renourishment. However, feeding activity, although the most frequently observed sanderling behavior throughout the study period, was significantly lower after renourishment at Transects 5 and 6 (Appendix L, pages L-12 through L-14). Resting behavior was also more common in the post-renourishment period, with significant differences at Transect 5. Pre- and post-renourishment sanderling flying behavior was similar to that found at the control transect. Transect 2 was not analyzed due to the lack of pre-nourishment survey records.

The increase in resting displayed by shorebirds after renourishment may have been due to the greater resting area provided by beach renourishment. Trends in sanderling feeding behavior could be related to the impact of beach renourishment on benthic invertebrates, which are, not only the main prey item for shorebirds, but also the community most likely to be effected by beach renourishment. The post-

renourishment decline in foraging observed at many of the transects may have been a product of the lower foraging profitability of renourished transects or the increased value of renourished transects as resting, rather than feeding, areas. Overall, however, despite the importance of benthic prey, the evidence that renourishment affected feeding behavior is tenuous, as both willets and shorebirds as a whole exhibit feeding behavior similar to the control transect. Although it is possible that less food was obtained while foraging at renourished beaches, the data do not suggest that beach renourishment substantially altered feeding behavior.

4.12 Piping Plover Observations. Fifty-seven Piping Plovers (*Charadrius melodus*) were noted during surveys from all Brunswick County transects. Over 80 percent of all Piping Plovers were recorded from Transect 4 (26 birds) and Transect 11 (20 birds) (Table 33). Seven birds were recorded from Ocean Isle Beach. Piping Plovers were recorded from Transects 1, 2, 4, 8, 11, and 12. Most birds were recorded at inlet transects (84 percent). Percentages of birds recorded in microhabitats were intertidal/surf at 74 percent, beach at 26 percent, and dunes at 0 percent. Percentages of birds in each activity category were feeding at 77 percent, flying at 4 percent, and resting at 19 percent. No nesting attempts were noted, nor were any birds present during the peak of the breeding season (10 May - 30 June).

5.0 SUMMARY

A summary of species richness, abundance, habitat use and recorded activity by transect is found in Table 34 for waterbirds and Table 35 for shorebirds. Abundance and species richness for both shorebirds and waterbirds were generally greatest during fall and some of the spring months. The lowest abundance and richness numbers generally occurred in winter. A comparison of all transects showed that species richness and abundance was highest for waterbirds at the cape transect. Beach and inlet transects had similar waterbird richness, while waterbird abundance was higher at beach transects compared to inlet transects. Shorebird abundance was greatest at inlet transects while richness was similar at all transect types.

Compared to two other studies in North Carolina, the second-year data from Brunswick County are generally similar to a study conducted in New Hanover County in the mid 1980s (Smith 1988). The top five most abundant (percentage of the total individuals observed) species were the same for both waterbird and shorebird categories (Figures 19 and 20; Smith 1988). In Brunswick County, the five most abundant species comprised 80 percent of all waterbird and 85 percent of shorebird individuals, compared to 90 percent of waterbirds and 82 of percent shorebirds in New Hanover County, N.C. Mean number of shorebirds per km by transect ranged from 8.0 to 63.4 for this study. Mean number of shorebirds along the Outer Banks were 50 birds/km (range of 31 to 74) during the spring and 68 birds/km (range of 36 to 117)

during the fall (Dinsmore et al. 1998).

Tide was a significant factor in abundance and species richness; however, the effect varied with bird species and transect type. At most transects, whether beach, cape, or inlet, greater numbers of waterbirds were surveyed at high tide compared to low tide. Waterbird richness was generally similar at high and low tide. Shorebirds exhibited a different pattern of behavior. Abundance and species richness were greatest during high tide at inlet transects only. At the Beach and Cape sites, tide appeared to have little effect on shorebird richness or abundance.

Waterbird abundance did not appear to be altered by beach renourishment. T-tests revealed no significant differences in the Δ_b and Δ_a for waterbird abundance at any renourished transect. A week-by-week comparison of sampling dates indicates that control abundance and was similar to abundance at the renourished transects in the before and after period for most survey weeks, and that the greater mean number of birds at the treated transects during post nourishment may have been due to a few weeks in which abundance at the renourished transects was exceptionally high.

The relationship between renourishment and waterbird species richness was variable. The Δ_a for species richness was higher than Δ_b at Transects 2, 5, and 6, with significant differences for Transects 5 and 6. The opposite was found for Transect 9, in which richness was consistently lower compared to the control during the post nourishment period. However, the difference in species richness was less than one bird/km/survey for most transects. Consequently, any renourishment effect, whether adverse or beneficial, seemed to be minor.

Two individual waterbird species, laughing gull and royal tern, were examined. For both species abundance showed patterns similar to those of waterbirds as a whole. All transects, except Transect 2, had a higher delta value in the post-nourishment period compared to the pre-nourishment period. For most transects, control and renourished sites track well before and after renourishment, except for occasional spikes in abundance at the renourished sites. Therefore, the differences in the delta values may have resulted from natural variability or short-term changes resulting from renourishment.

For shorebird abundance, no significant renourishment effect was found at any transect, though BACI analysis could not be performed on Transects 2 and 5 due to pre-nourishment variability at the control site. Similarly, shorebird richness at the control site was highly variable throughout the monitoring period, therefore, any renourishment effect, if present, was difficult to discern. Though Transect 9 had a significantly lower Δ_a, the mean difference in delta values was less than one species/km/survey. No other renourished transect had significantly different pre- and post renourishment delta values.

Several shorebird species were considered separately. For willets no significant differences in Δ_b and Δ_a were found. Though renourishment did not appear to alter willet abundance, it should be noted that the delta values were highly variable in both the before and after period, which made any renourishment effects difficult to discern. Renourishment did not appear to affect habitat use by sanderlings. Delta values for sanderling abundance were not found to differ in the pre- and post-nourishment period. BACI analysis did not reveal any renourishment effects on Black-bellied plovers or ruddy turnstones. However, both species showed strong seasonal patterns in visitation and, for a large number of surveys, neither species was observed at the control nor treatment transects.

Neither aggregate nor individual waterbird and shorebird data suggested that beach renourishment affected tidal habitat preference. No significant interaction between renourishment period and abundance at high and low tide was found at any transect for waterbirds. Nor was a significant interaction found for the two waterbird species laughing gull and royal tern. No significant interaction between renourishment and individual or total shorebird abundance at high and low tide was found at any transect, except for sanderlings at Transect 5. Though renourishment could have influenced sanderling tidal abundance at Transect 5, no renourishment effect was evident for this species at the other transects.

The primary effects of renourishment may have appeared in the form of changes in bird activity. At all renourished transects, waterbirds exhibited greater resting behavior and less flying behavior after renourishment, with significant differences at Transects 2 and 9. The control transect sometimes displayed similar behavior during the same time period, but no significant differences in pre- and post-nourishment resting were detected. Laughing gulls and royal terns showed pre- and post-nourishment behavioral patterns similar to overall waterbird behavior. However, it should be noted that royal terns at the control transect displayed temporal patterns of flying and resting behavior similar to that found at the renourished transects. Total waterbird, laughing gull and royal tern feeding behavior did not appear to be altered by renourishment.

As with waterbirds, shorebird resting behavior seems to have been most affected by beach renourishment. The percentage of resting birds was significantly higher in the post-nourishment period at Transects 2, 5, and 6. Willets resting behavior was temporally similar to that of shorebirds as an aggregate, but statistically significant differences in resting activity before and after renourishment were not present at any transect. Resting behavior by sanderling was also more common in the post-renourishment period, with significant differences at Transect 5. Sanderling feeding activity was significantly lower after renourishment at Transects 5 and 6. Willet and sanderling flying behavior did not appear to be altered by renourishment.

The increase in resting displayed by waterbirds and shorebirds after renourishment may have been due to the greater resting area provided by beach renourishment. Trends in sanderling feeding behavior could be related to the impact of beach renourishment on benthic invertebrates, but the data do not suggest that the renourished beach substantially altered shorebird feeding behavior as a whole.

Beach renourishment has the potential to affect avian beach communities in a number of ways. The increase in beach area after renourishment could attract birds and increase shorebird and waterbird abundance. Alternately, avian abundance could decrease if food resources and/or availability are reduced in the post-renourishment period. These same changes could also lower species diversity if specialist feeders make less frequent visits to renourished beaches with disturbed benthic habitat. In addition to population changes, renourishment could alter bird behavior and habitat use as well.

Despite the potential for community changes at renourished beaches, in this study, beach renourishment was not found to alter the overall abundance or species richness of waterbirds and shorebirds. A clear renourishment effect was not evident for individual species either, including willet and sanderling, which are heavily dependent on beach habitat. Moreover, examination of weekly survey data revealed no consistent short-term changes in abundance or species richness in the weeks following beach renourishment.

Although the results did not support the existence of renourishment impacts on richness and abundance, it is possible that, in some instances, the impacts went undetected. For example, despite the BACI design, high variability, both between and within seasons, lowered the power of the statistical tests. Variability in shorebirds was especially pronounced. Because most statistical tests were non-parametric, statistical power analysis could not be performed. However, the variability present in the data suggests that power of some tests was low. Also, while no renourishment effect on abundance was evident for the most frequently encountered shorebirds (e.g. willet and sanderlings), it was not possible to evaluate most species because of their seasonal or infrequent habitat use at Brunswick county beaches. Consequently, it is possible that renourishment impacts exist for some individual species. Overall, however, there was little evidence for significant alterations in avian abundance and richness after beach renourishment.

The data do provide evidence for changes in bird behavior following renourishment. After beach renourishment, waterbirds and shorebirds spent more time resting and less time flying, presumably due to the greater resting area available upon renourishment. Despite the likely post-renourishment disturbance to benthic food resources, there was only ambiguous evidence for renourishment altering feeding

behavior. Feeding activity in both willet and shorebirds as a whole did not change upon renourishment. In contrast, sanderling did display a significant decrease in feeding activity at two transects during the post-renourishment period. Overall, renourishment did not appear to produce major alterations in feeding behavior, but changes in feeding behavior of individual species may have gone undetected because most shorebirds were uncommon, seasonal visitors.

Regardless of whether feeding behavior changed, the amount of food obtained during foraging may have declined in the post-renourishment period, at least until benthic communities recovered. However, the potential effects on foraging efficiency were not evaluated in this study.

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FIGURES

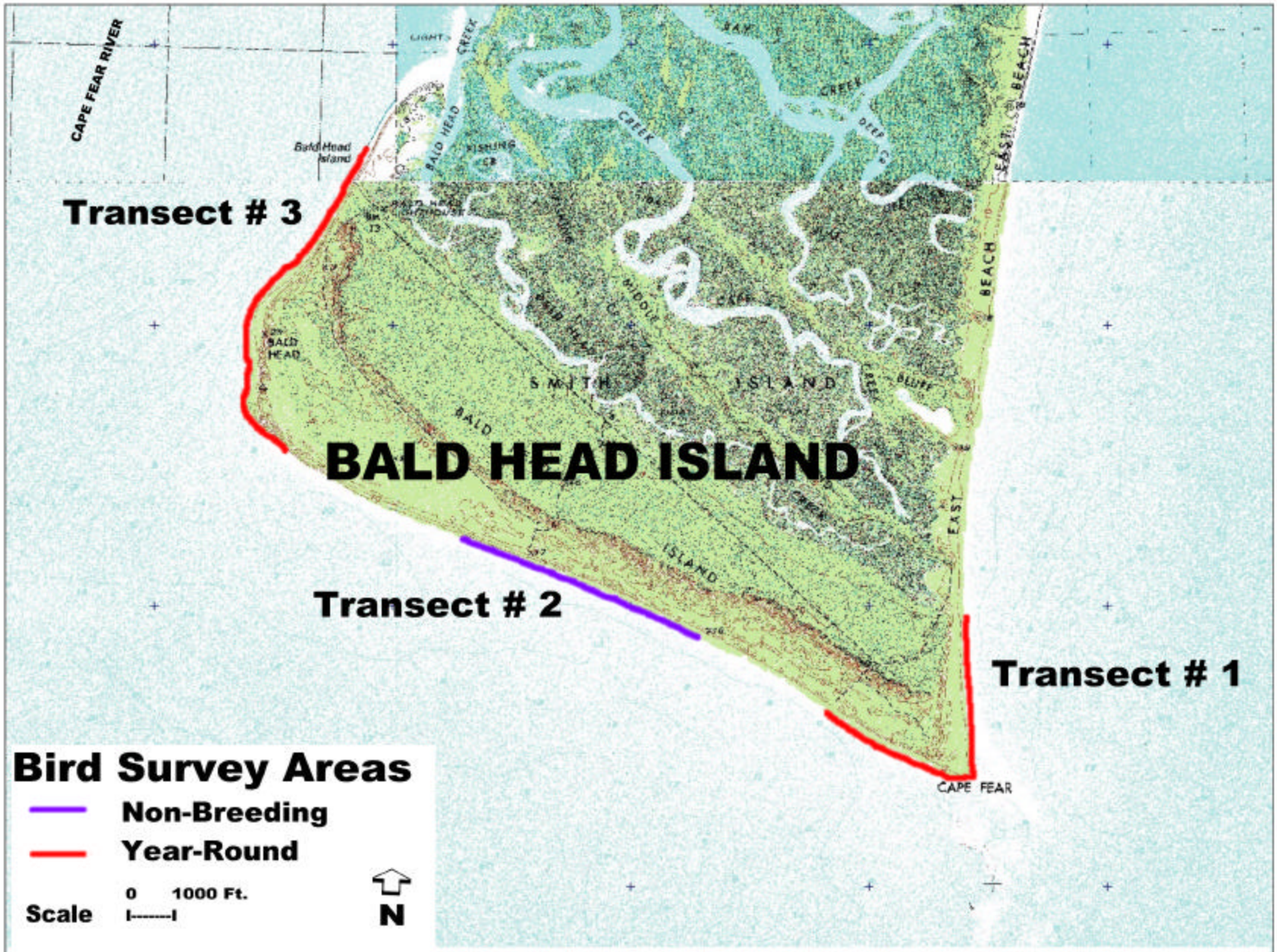


Figure 1. Location of Transects 1 through 3 on Bald Head Island, Brunswick County, N.C.

 1000 ft Scale: 1 : 34,375 Detail: 13-0 Datum: WGS84

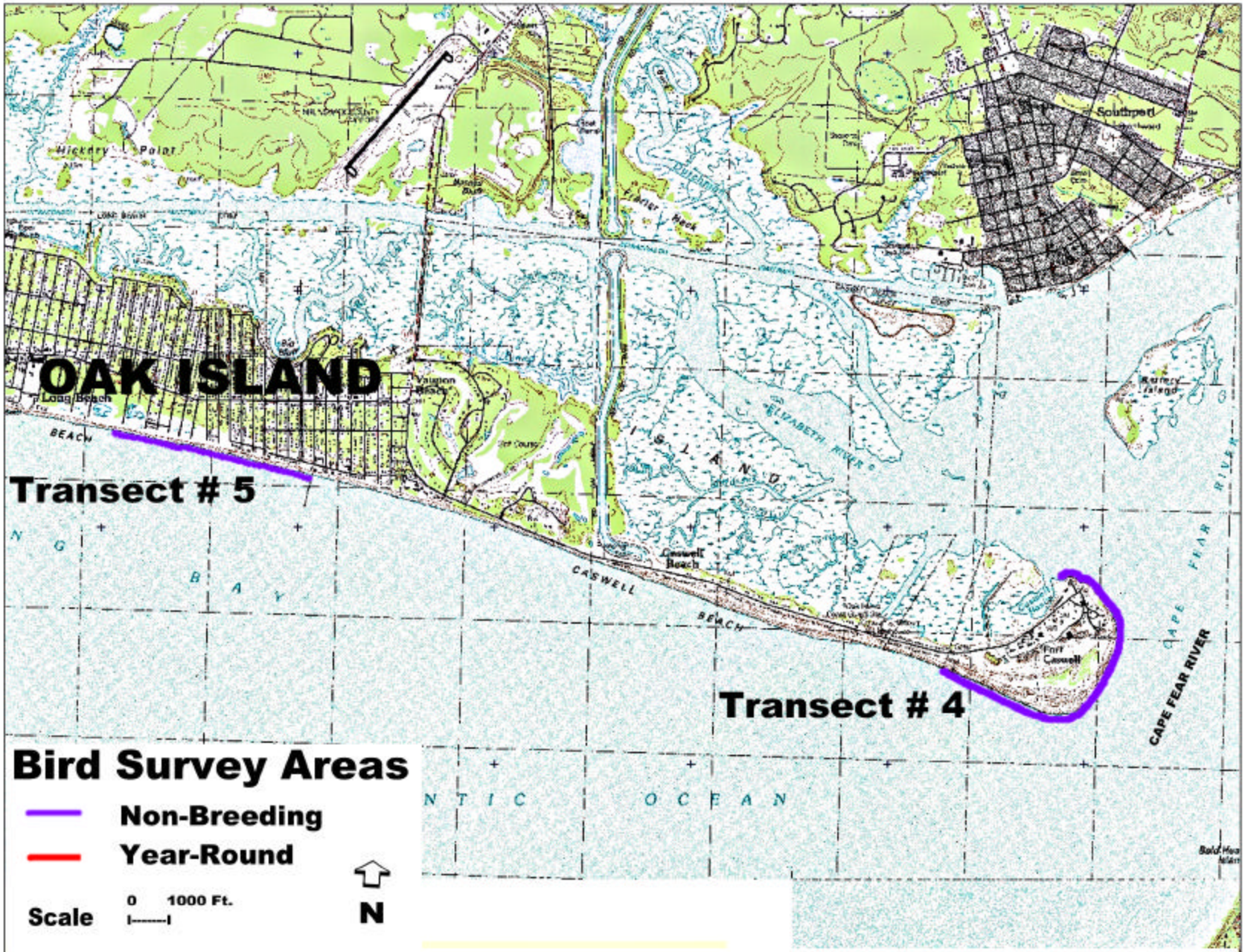


Figure 2. Location of Transects 4 and 5 on Oak Island, Brunswick County, N.C.

 1000 ft Scale: 1 : 40,625 Detail: 13-0 Datum: WGS84

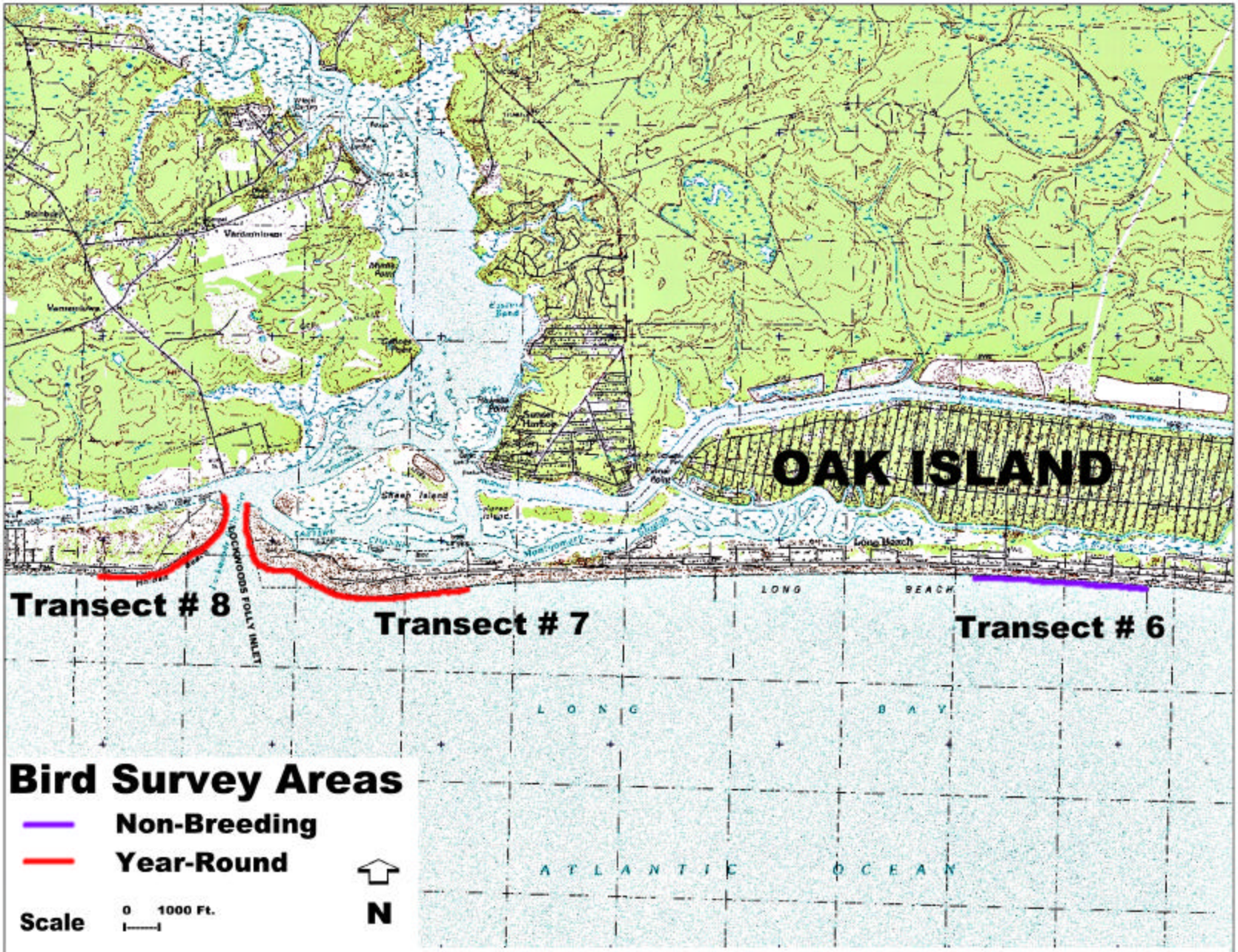


Figure 3. Location of Transects 6 through 8 on Oak Island and Holden Beach, Brunswick County, N.C.

 1000 ft Scale: 1 : 46,875 Detail: 13-0 Datum: WGS84

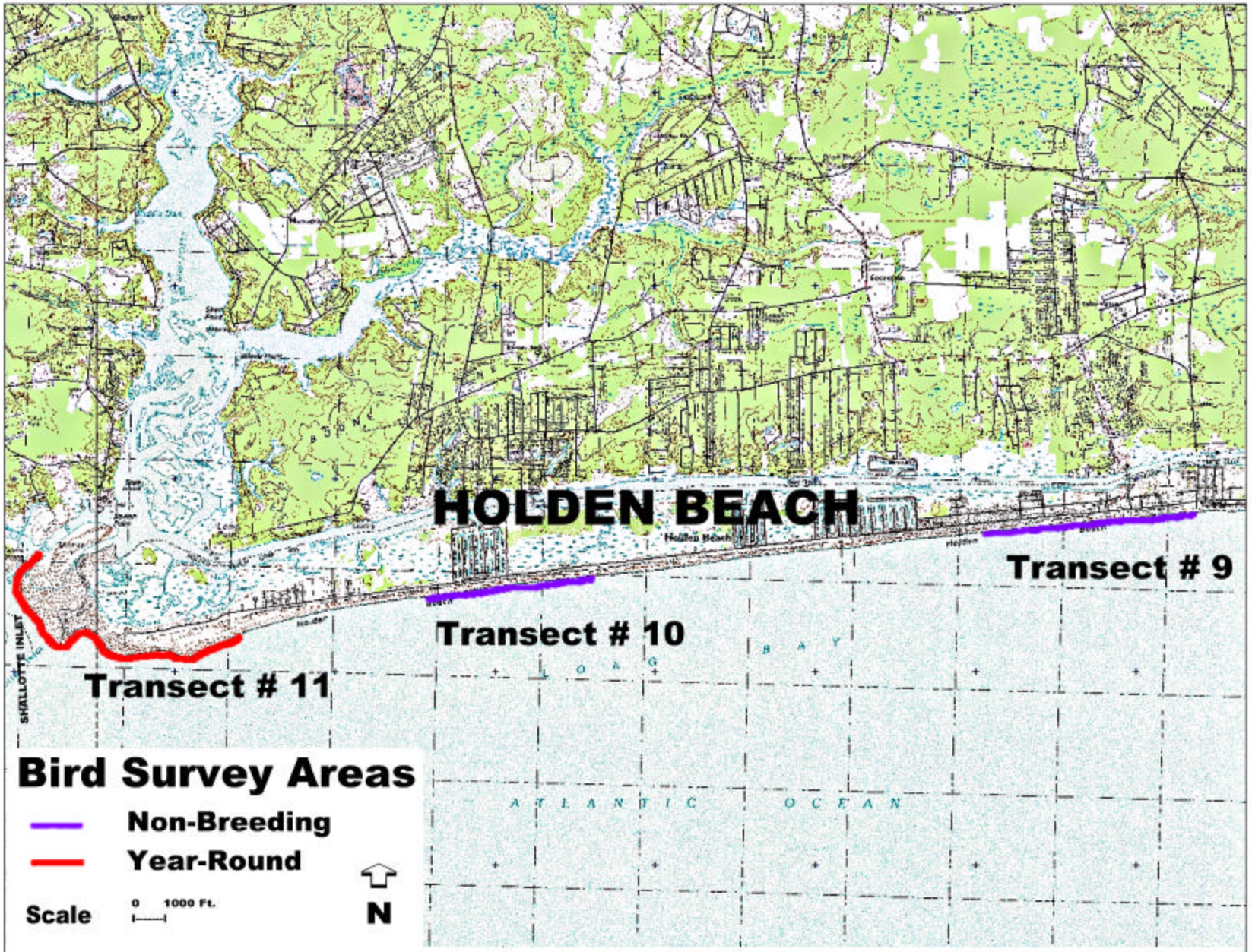


Figure 4. Location of Transects 9 through 11 on Holden Beach, Brunswick County, N.C.

 1000 ft Scale: 1 : 50,000 Detail: 13-0 Datum: WGS84

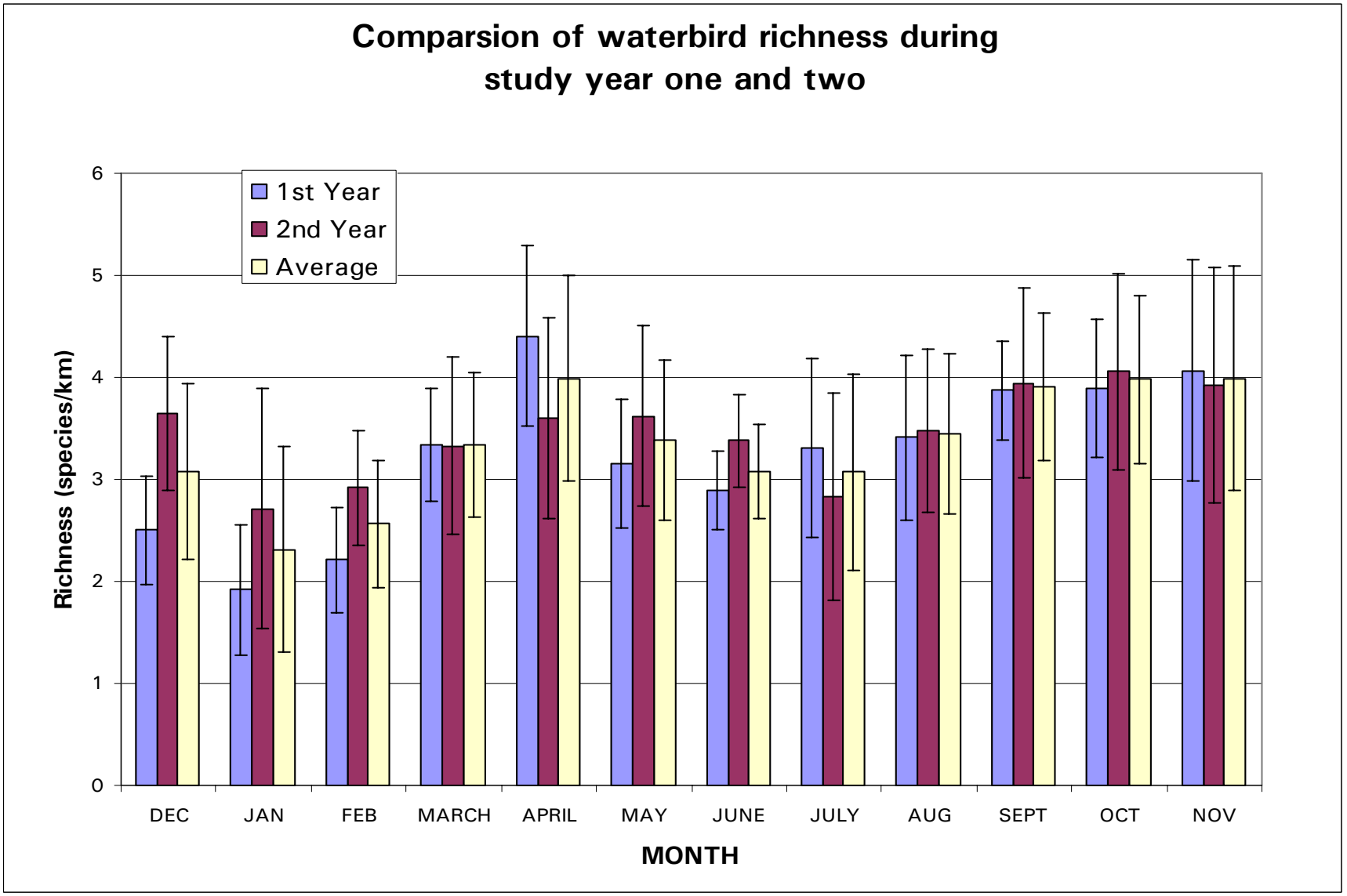


Figure 5. Comparison of waterbird richness during study year one and two.

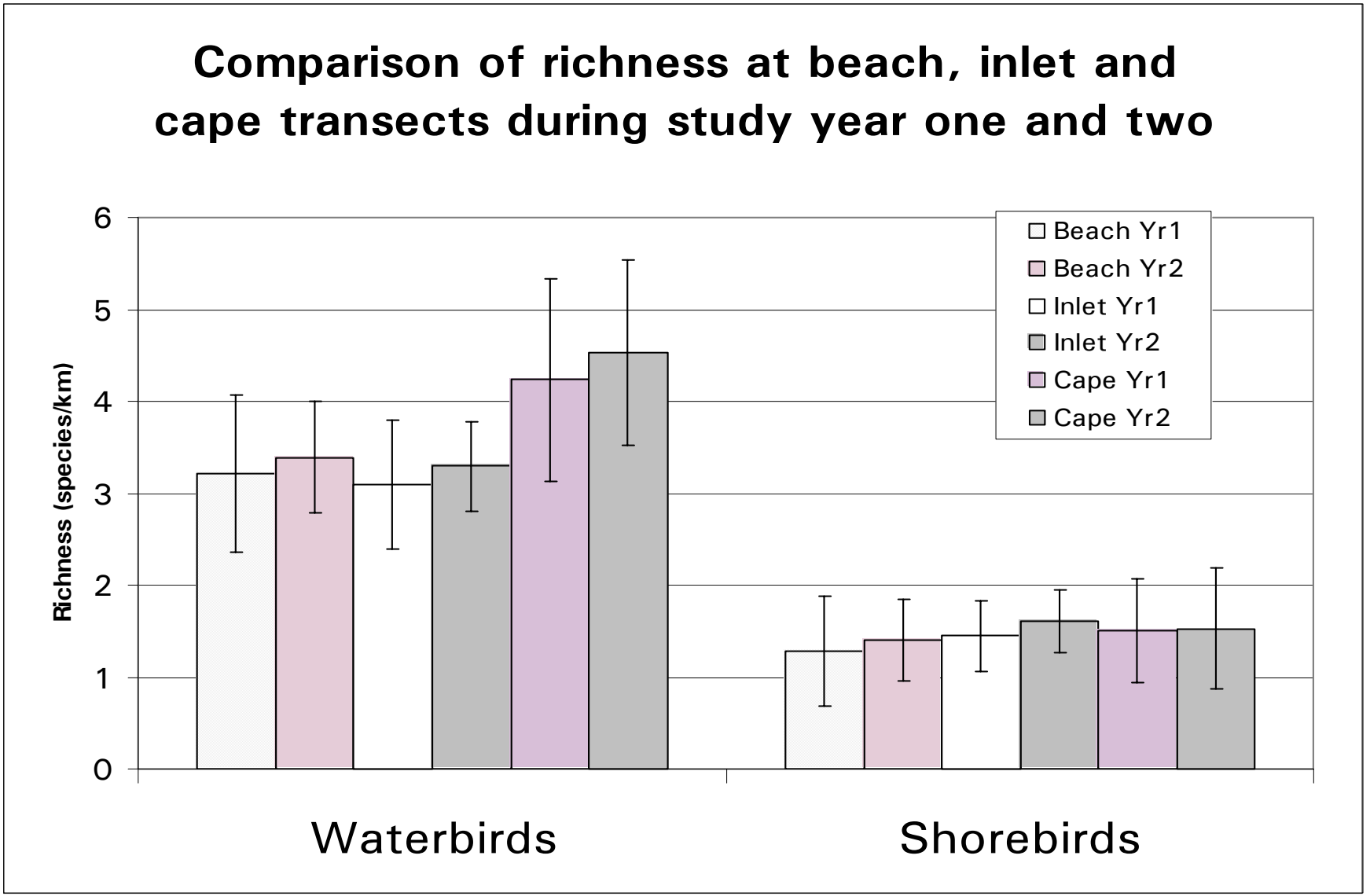


Figure 6. Comparison of richness at beach, inlet, and cape transects during study year one and two.

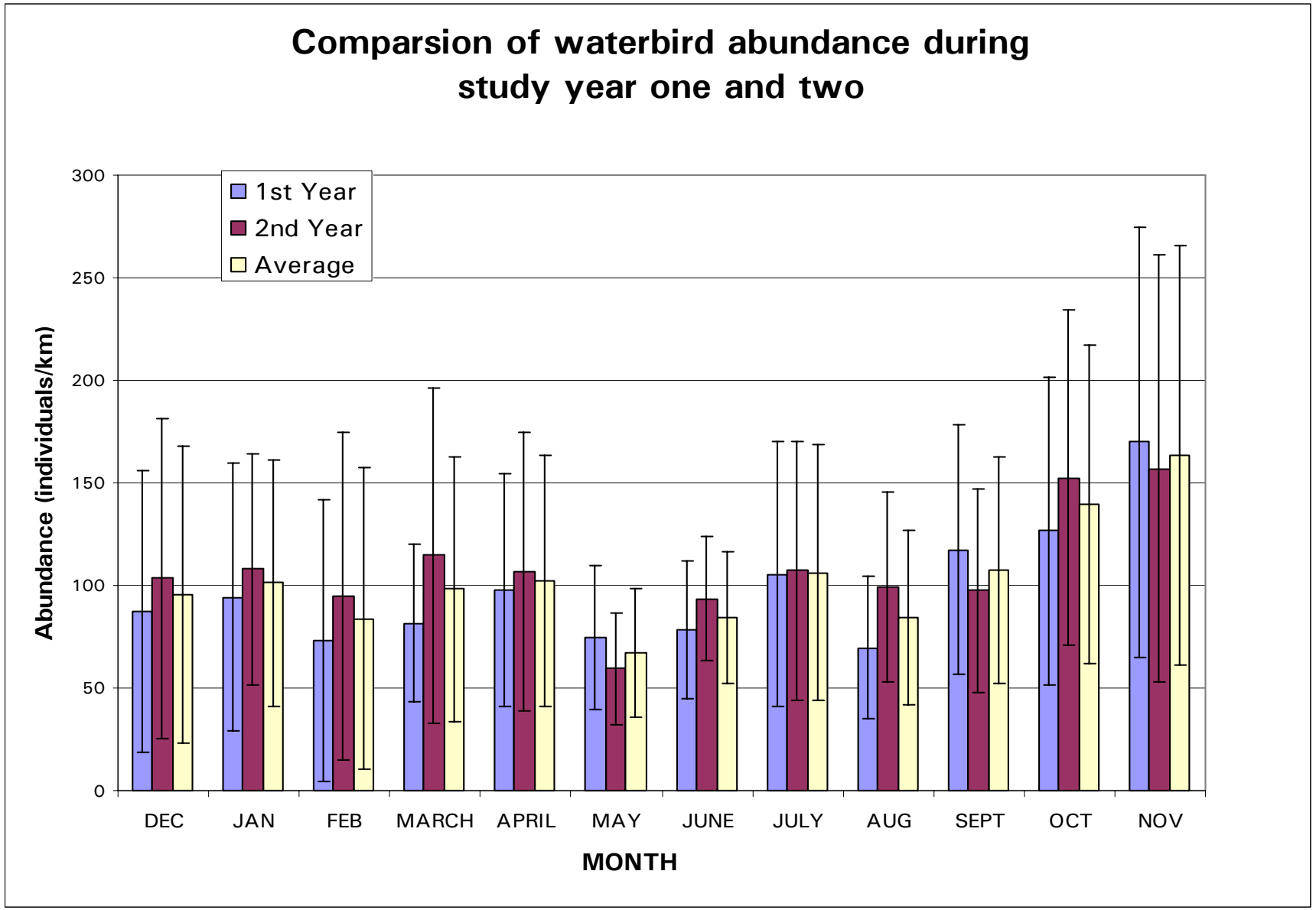


Figure 7. Comparison of waterbird abundance during study year one and two.

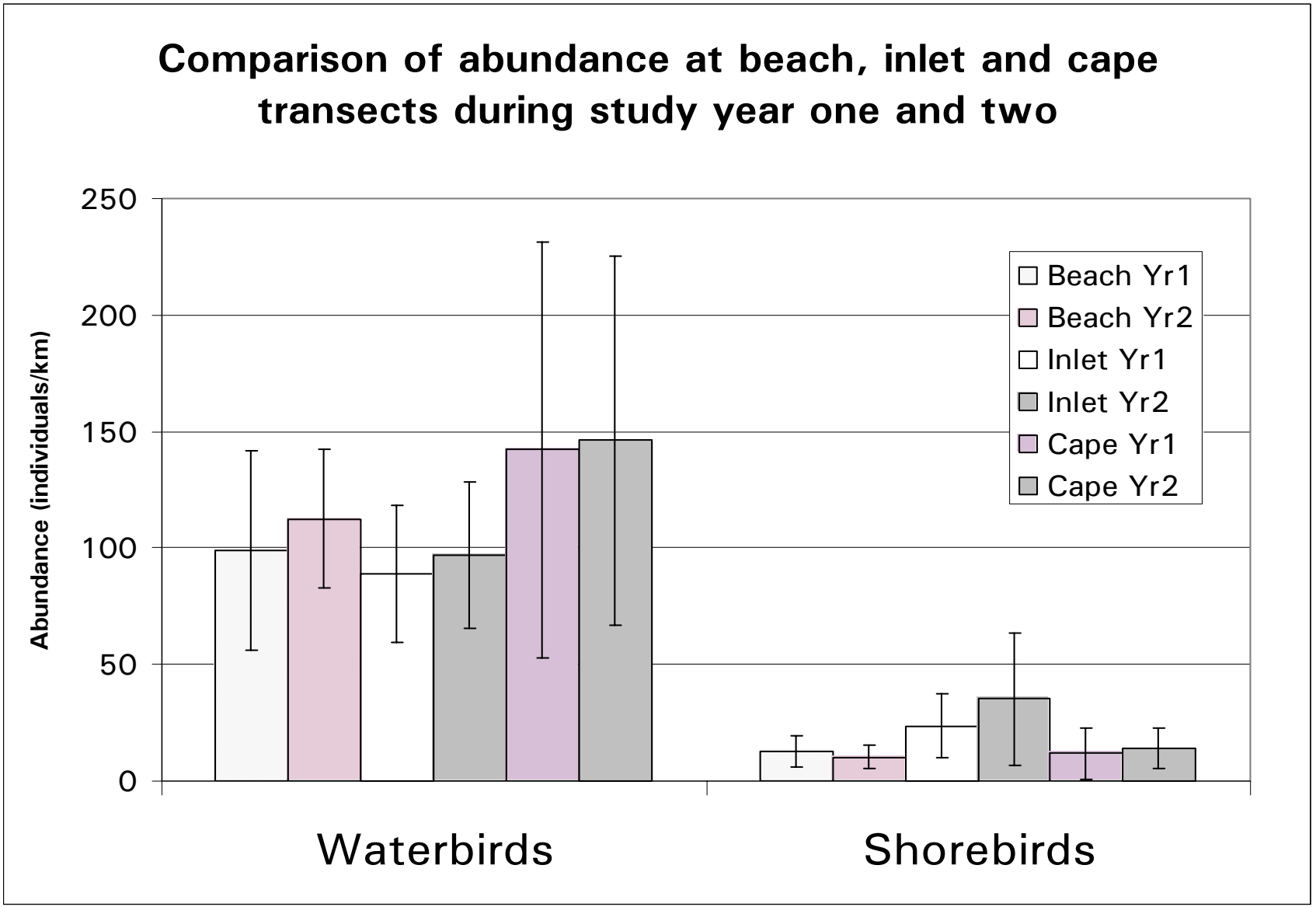


Figure 8. Comparison of abundance at beach, inlet, and cape transects during study year one and two.

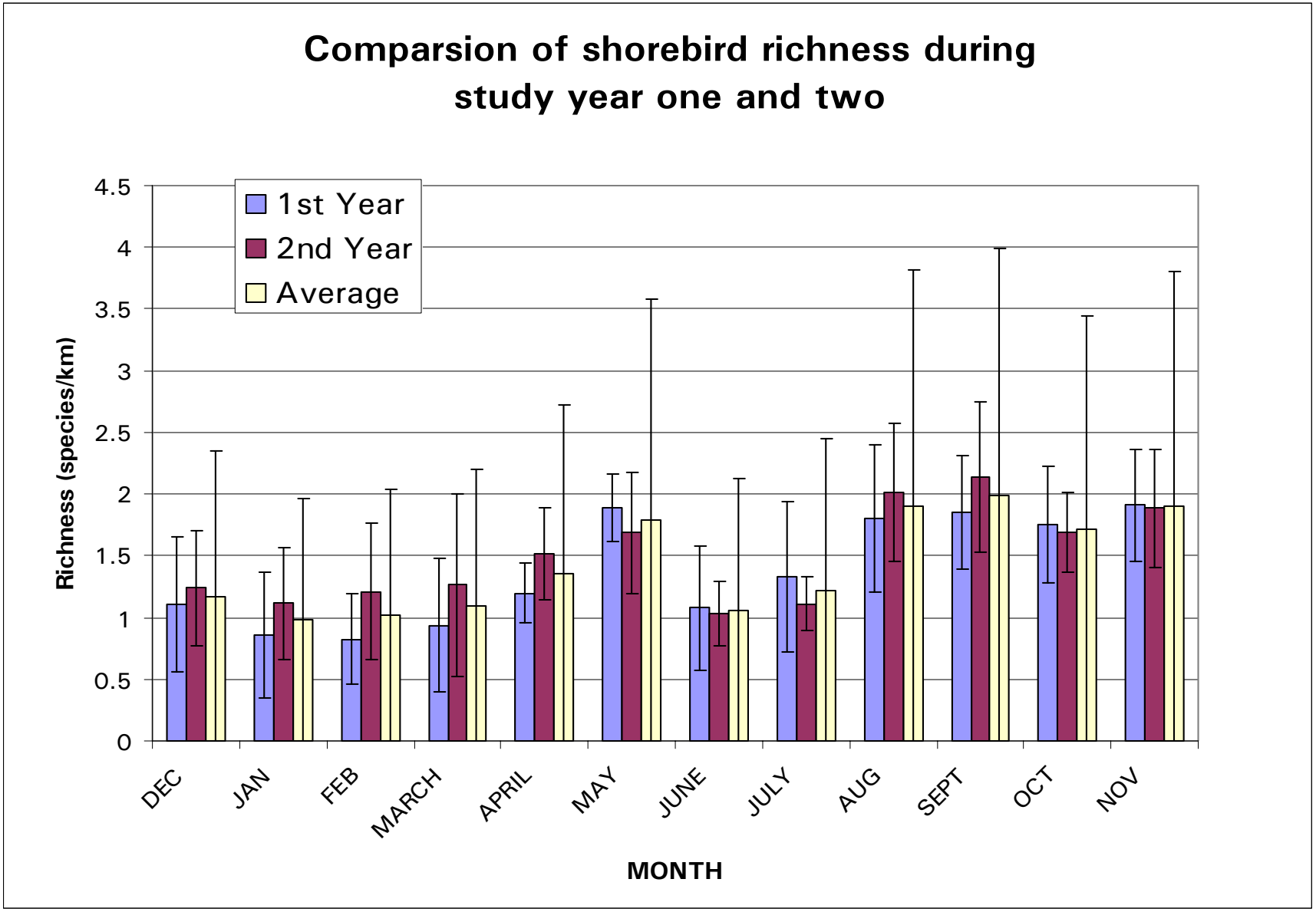


Figure 9. Comparison of shorebird richness during study year one and two.

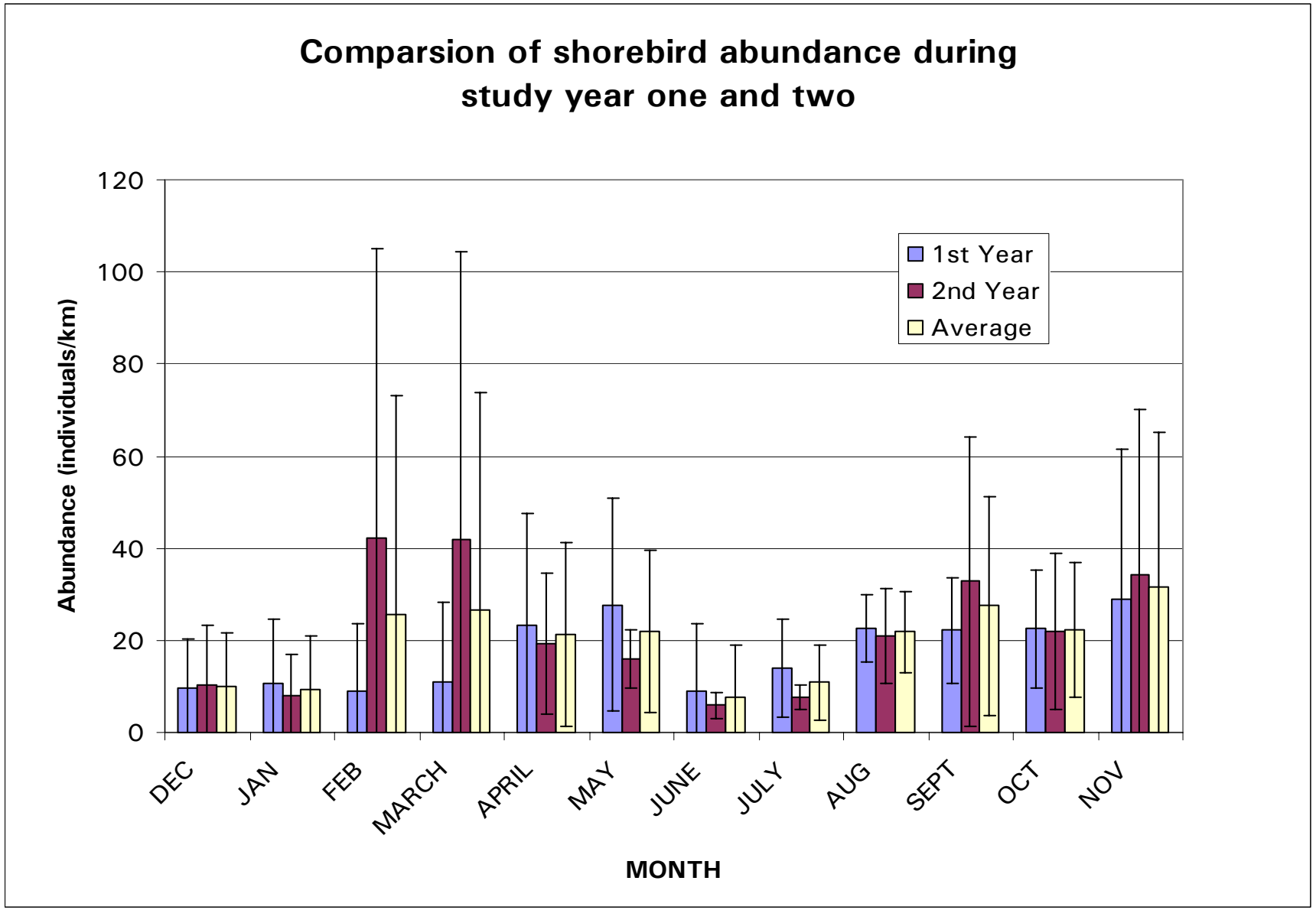


Figure 10. Comparison of shorebird abundance during study year one and two.

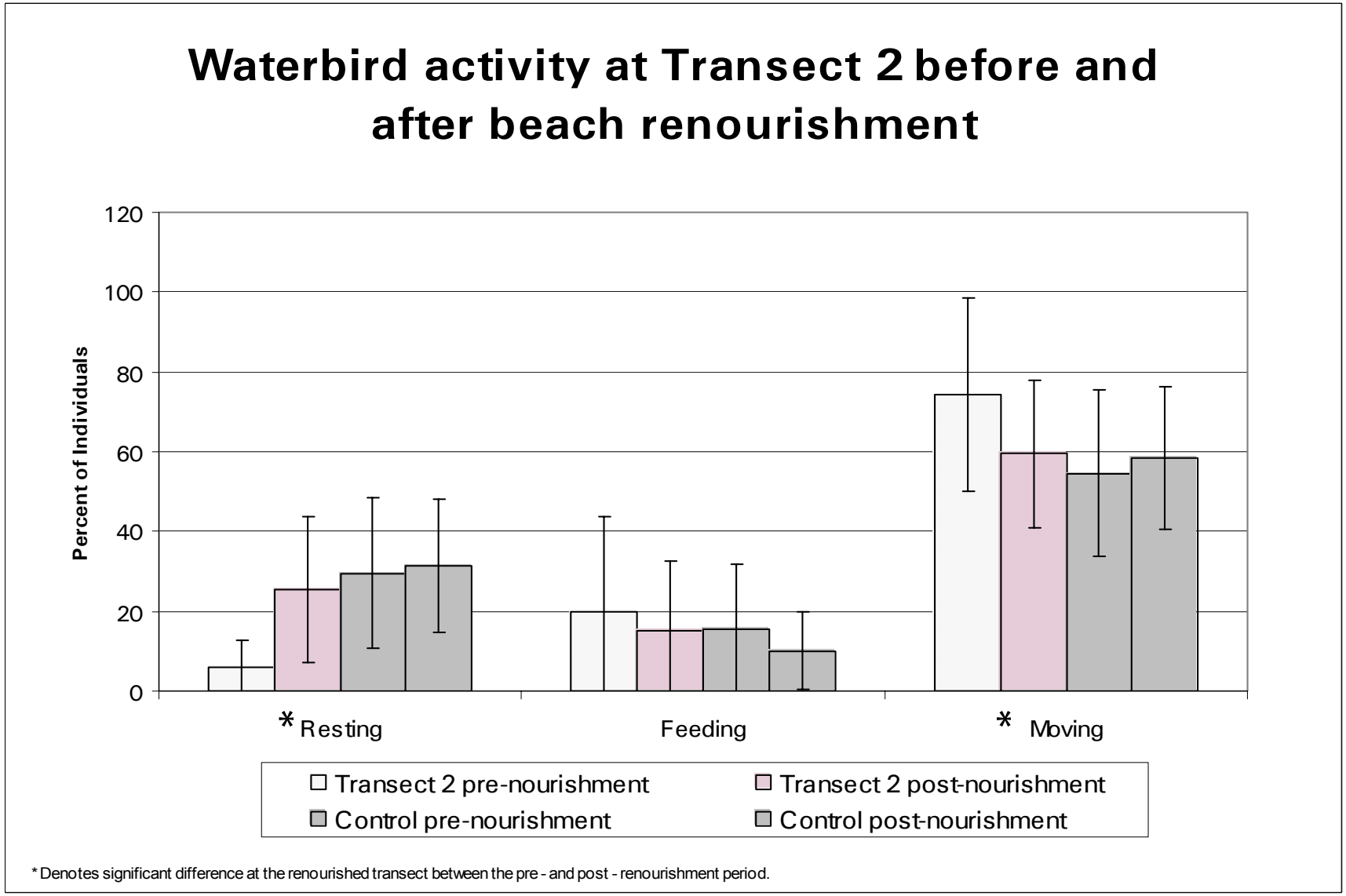


Figure 11. Waterbird activity (mean ± SD) at Transect 2 and the control during the pre - and post - renourishment period.

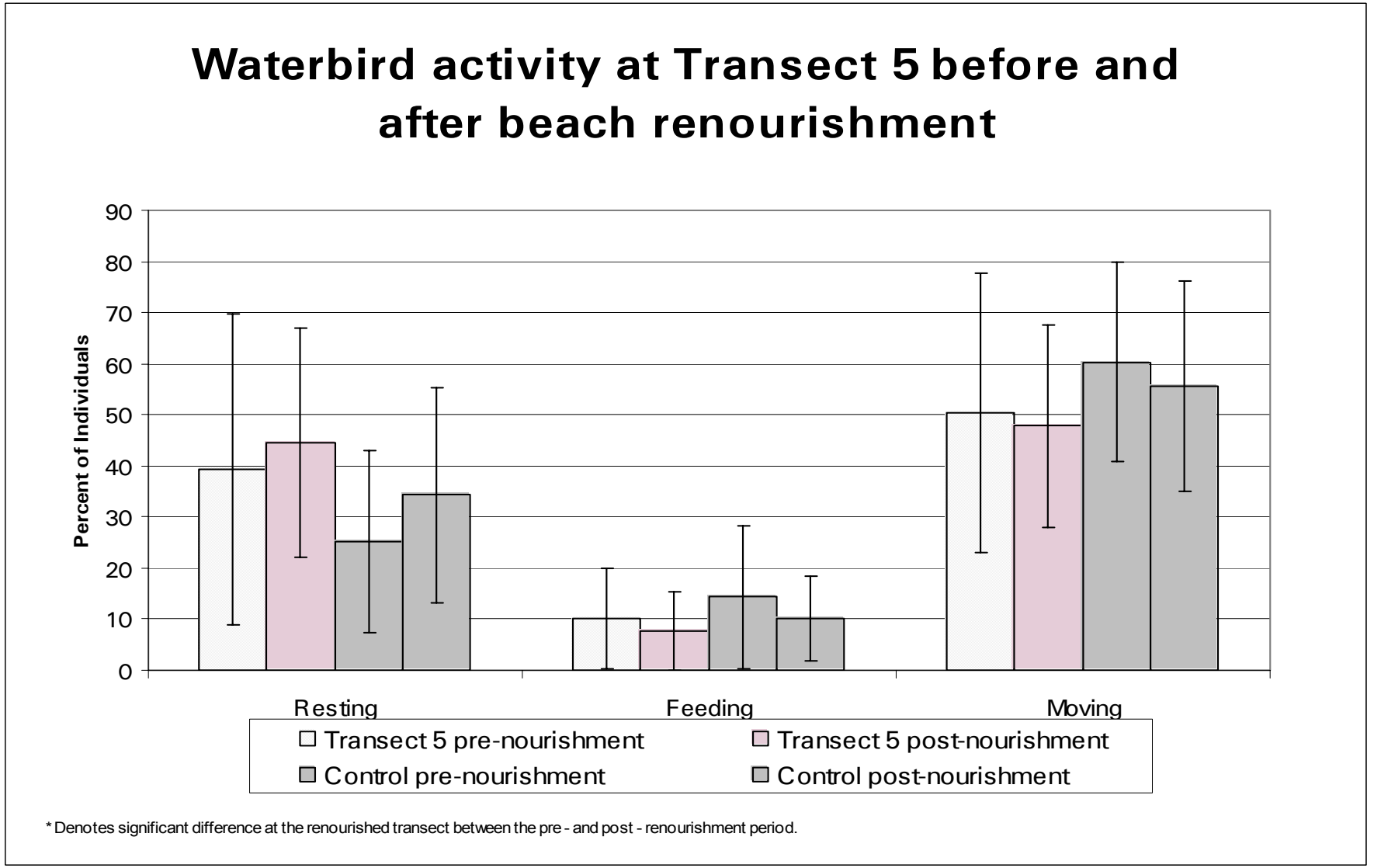


Figure 12. Waterbird activity (mean ± SD) at Transect 5 and the control during the pre - and post - renourishment period.

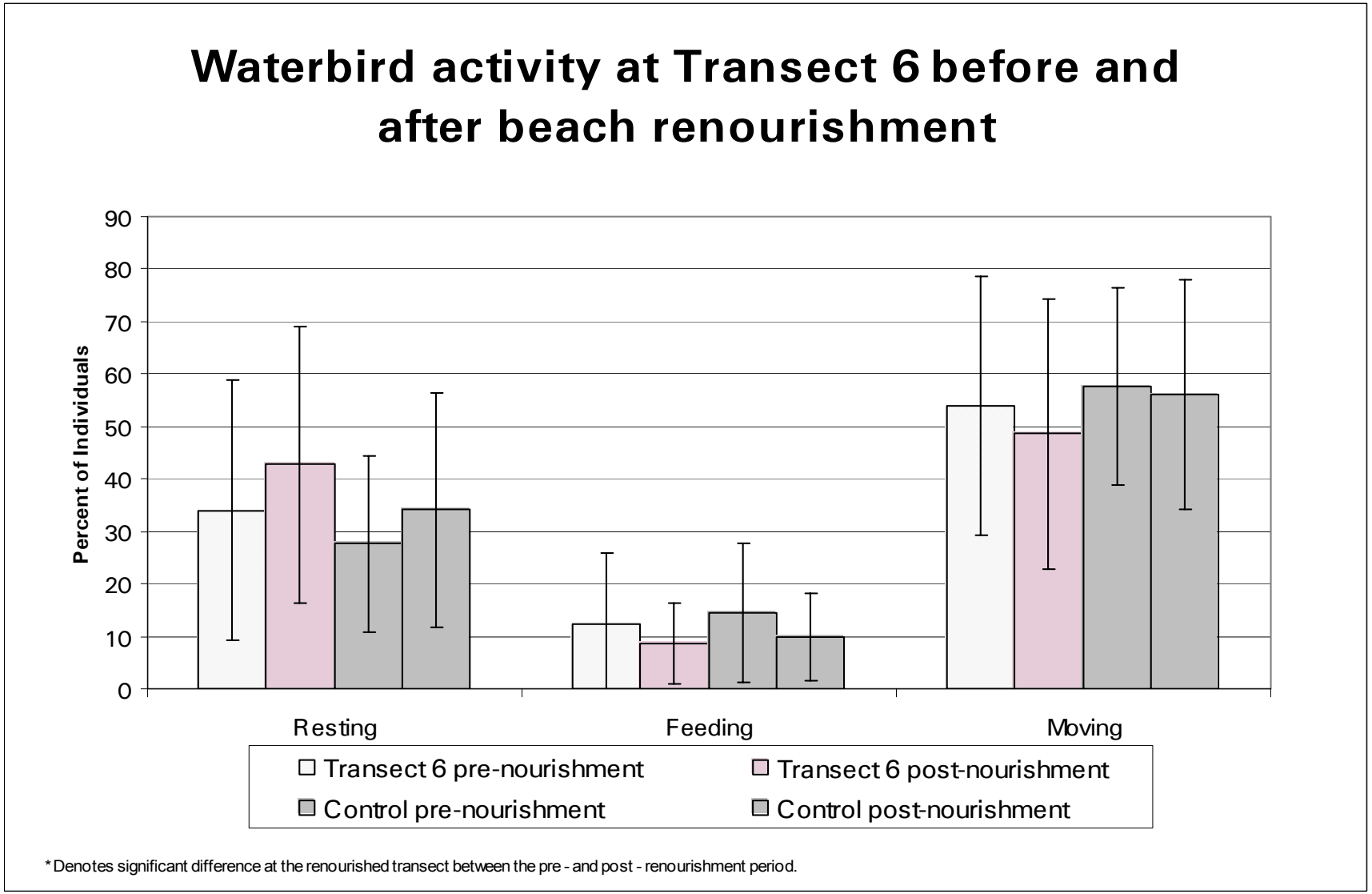


Figure 13. Waterbird activity (mean ± SD) at Transect 6 and the control during the pre - and post - renourishment period.

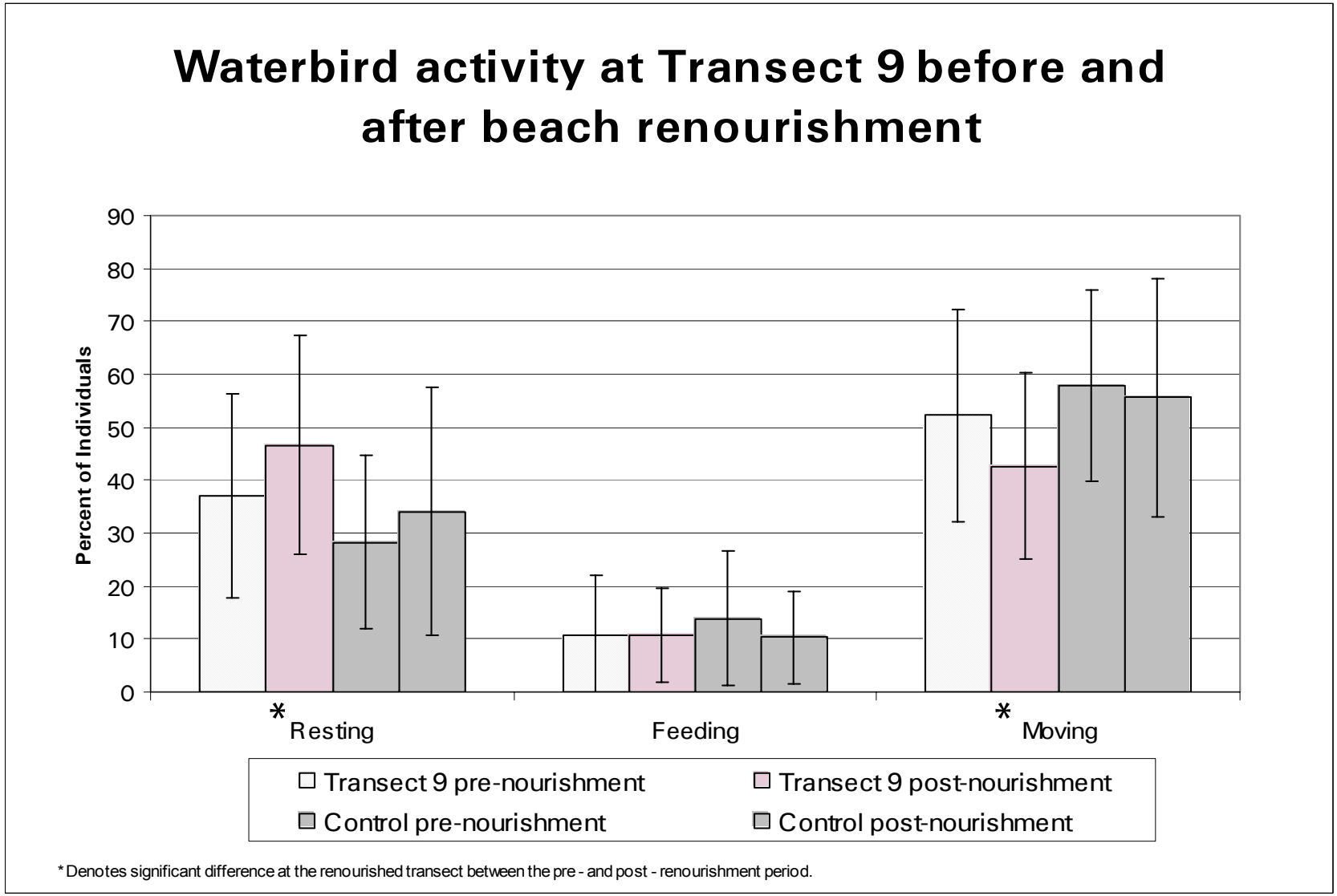


Figure 14. Waterbird activity (mean ± SD) at Transect 9 and the control during the pre - and post - renourishment period.

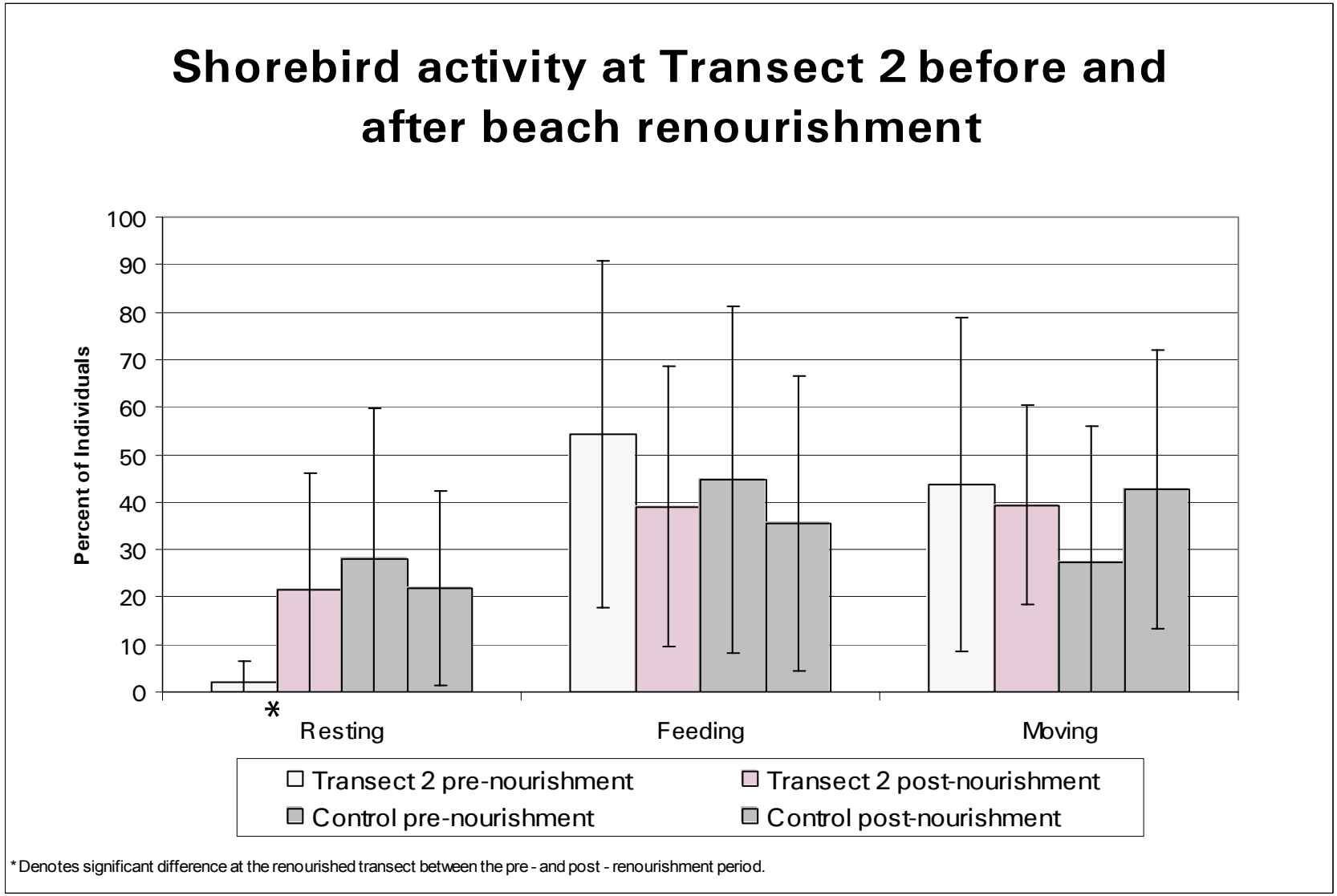


Figure 15. Shorebird activity (mean ± SD) at Transect 2 and the control during the pre - and post - renourishment period.

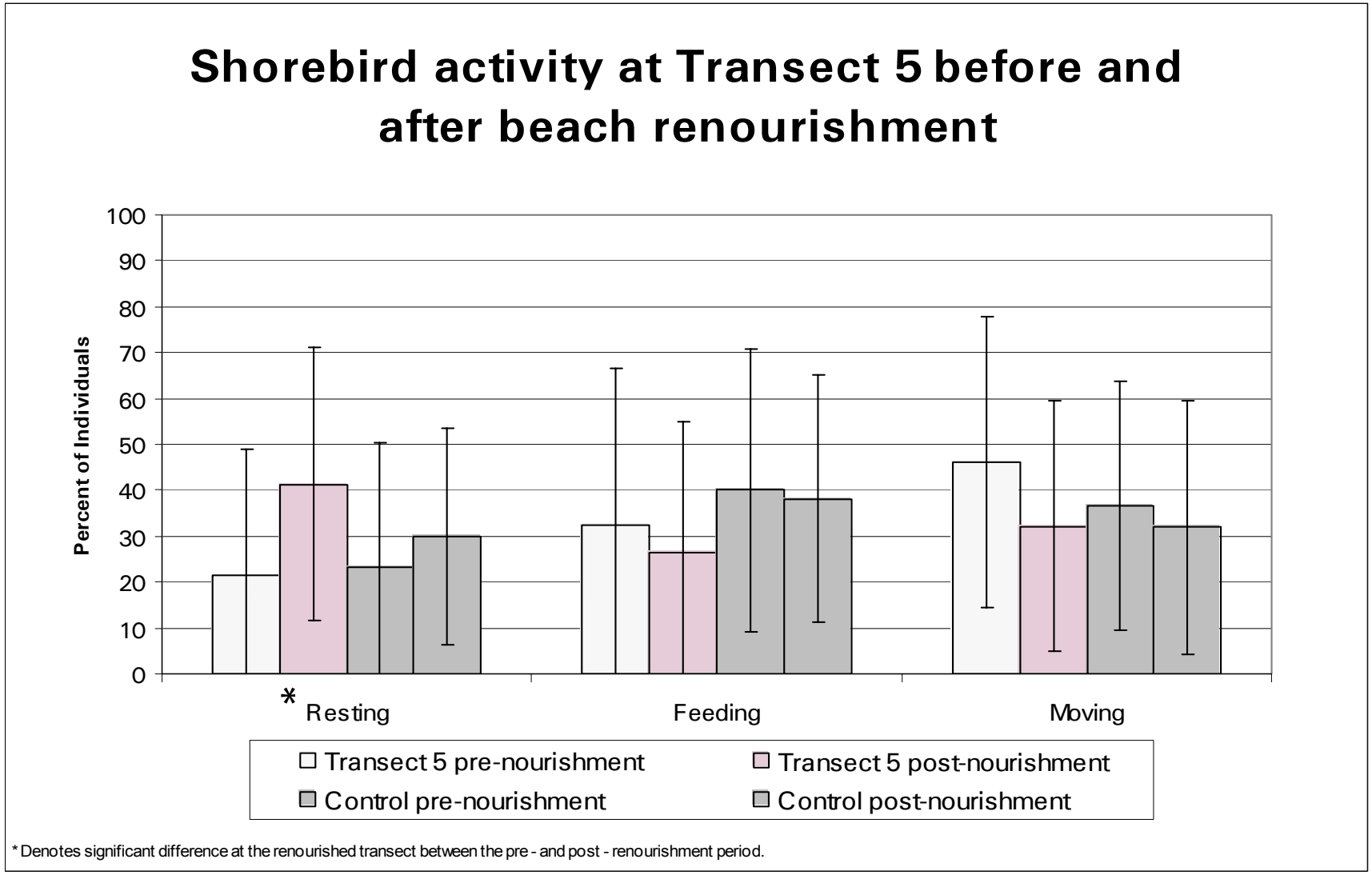


Figure 16. Shorebird activity (mean ± SD) at Transect 5 and the control during the pre - and post - renourishment period.

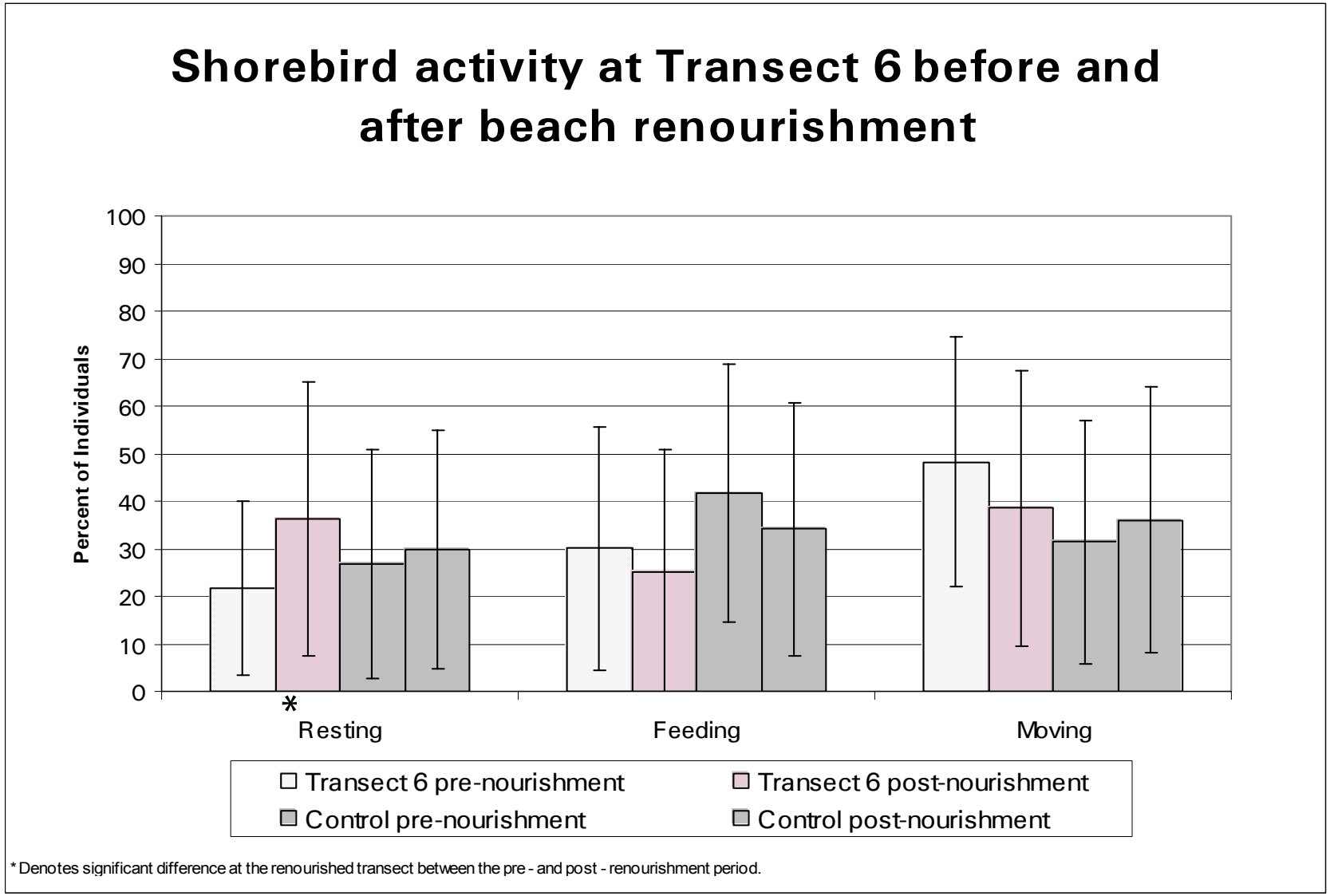


Figure 17. Shorebird activity (mean ± SD) at Transect 6 and the control during the pre - and post - renourishment period.

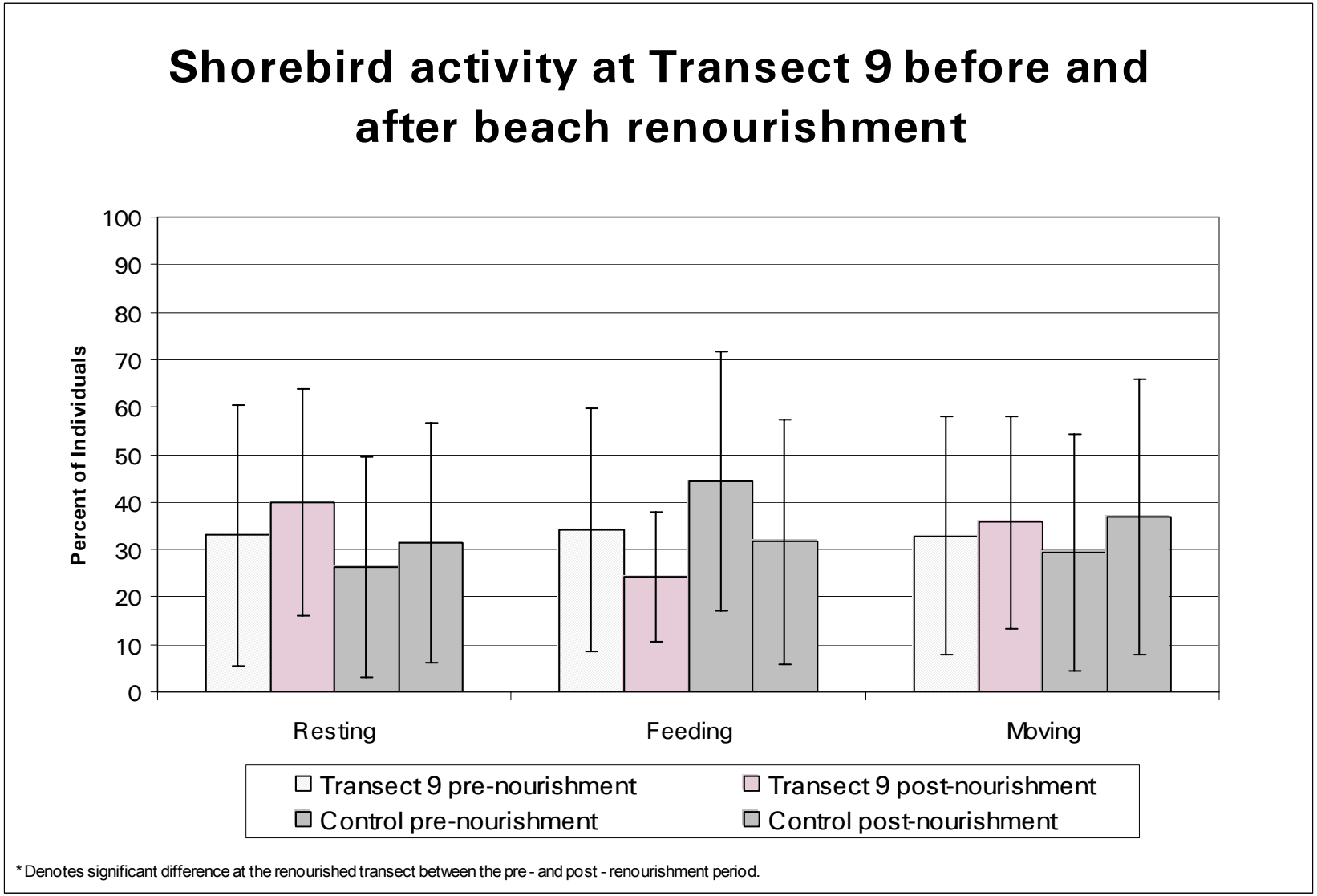


Figure 18. Shorebird activity (mean ± SD) at Transect 9 and the control during the pre - and post - renourishment period.

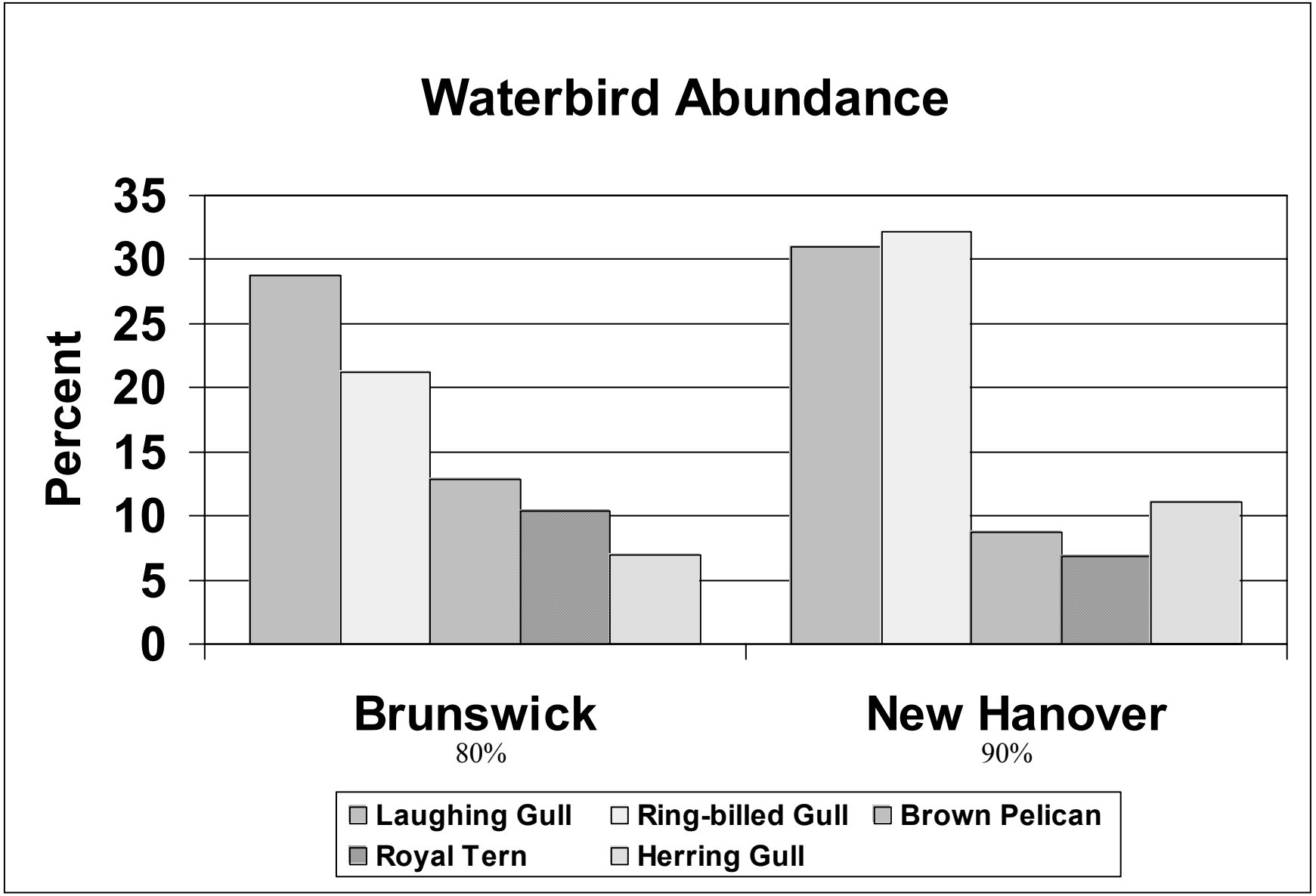


FIGURE 19. Five most abundant (percentage of total recorded) waterbirds from Brunswick County (this study) and in New Hanover County (Smith 1988).

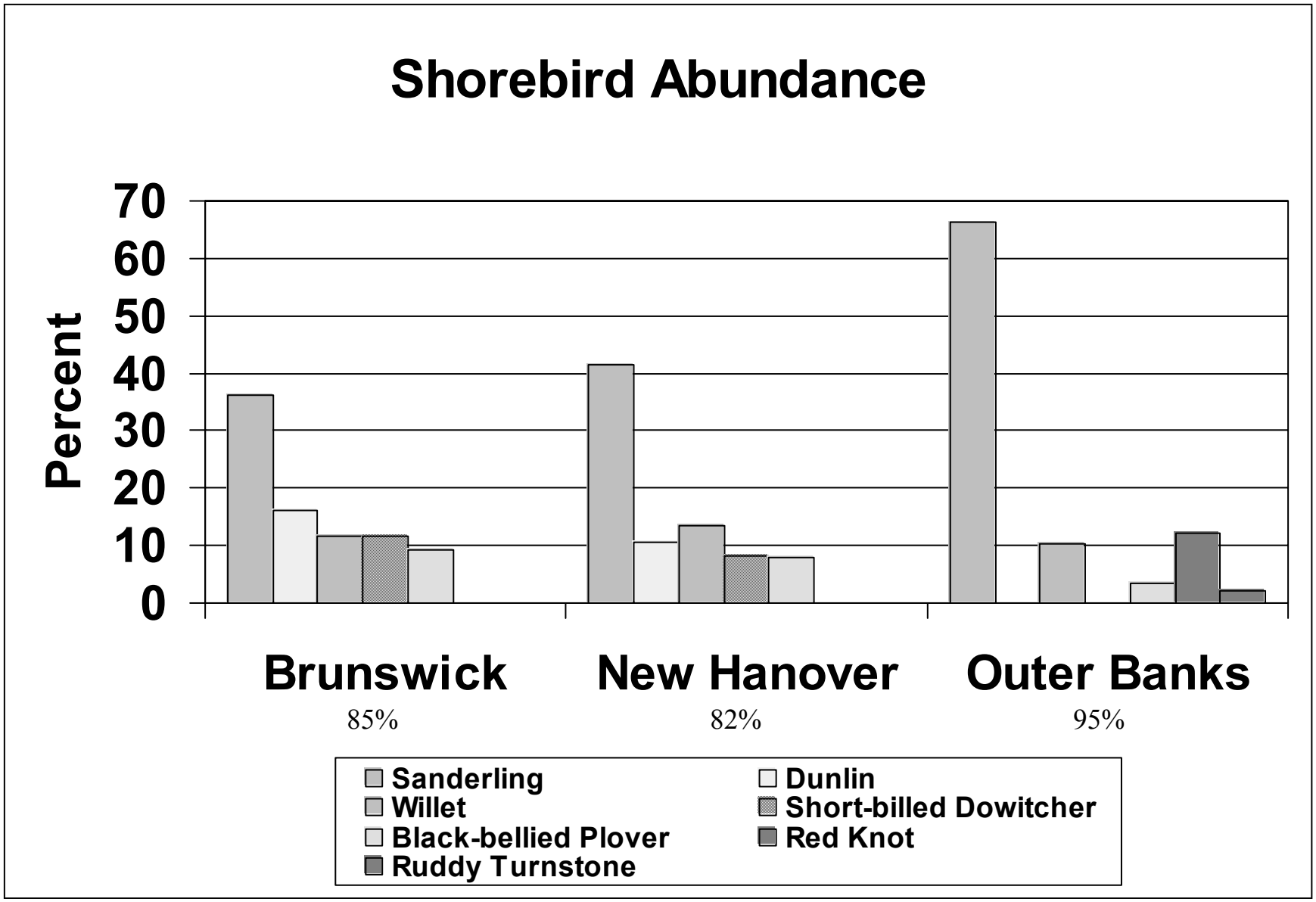


FIGURE 20. Five most abundant (percentage of total recorded) shorebirds from Brunswick County (this study), in New Hanover County (Smith 1988), and on the Outer Banks of N.C. (Dinsmore et al., 1998).

TABLES

Table 1. Summary of transect locations, features, and characteristics for Brunswick County bird surveys.

Transect #	Island	Site	Length (km)	# of Surveys	Frequency of surveys	Renourishment
1	Bald Head	Cape	1.6	46	year-round	—
2	Bald Head	Beach	1.6	40	non-breeding	May-June 2001
3	Bald Head	Inlet/river	2.4	46	year-round	Feb.-March 2001 (partial)
4	Oak Island	Inlet/river	2.4	40	non-breeding	—
5	Oak Island	Beach	1.6	40	non-breeding	Aug.-Oct. 2001
6	Oak Island	Beach	1.6	40	non-breeding	Nov. 2001
7	Oak Island	Inlet	2.4	46	year-round	—
8	Holden Beach	Inlet	1.6	46	year-round	27 Nov. 2002
9	Holden Beach	Beach	2.4	40	non-breeding	Dec. 2001-Jan. 2002
10	Holden Beach	Beach	1.6	40	non-breeding	—
11	Holden Beach	Inlet	3.2	46	year-round	—

Table 2. Total waterbird individuals recorded for each species in each transect.

	Transect #											
SPECIES	1	2	3	4	5	6	7	8	9	10	11	Grand Total
Laughing Gull	1,379	505	2,146	1,911	4,977	4,382	3,991	2,656	4,499	2,590	2,055	31,091
Ring-billed Gull	872	615	1,879	911	3,202	3,700	2,450	1,549	3,884	1,649	1,656	22,367
Brown Pelican	1,579	511	833	914	855	1,014	1,481	1,323	1,090	526	1,080	11,206
Royal Tern	3,257	98	2,429	1,757	243	120	1,274	1,161	88	64	772	11,263
Herring Gull	1,079	116	855	851	539	446	724	457	676	283	709	6,735
Forster's Tern	831	218	680	186	439	232	731	377	485	89	1,157	5,425
Sandwich Tern	1,003	26	815	291	49	43	813	822	85	40	476	4,463
Double-crested Cormorant	551	29	134	1,929	43	64	44	98	39	35	145	3,111
Great Black-backed Gull	329	28	116	77	96	49	212	134	131	68	282	1,522
Black Skimmer	0	0	0	3	0	0	1,142	242	2	1	25	1,415
Common Tern	97	1	94	153	2	5	230	187	1	1	32	803
Caspian Tern	98	13	99	77	30	25	139	77	16	15	86	675
White Ibis	6	0	205	31	44	0	0	0	0	0	111	397
Least Tern	105	1	90	15	7	3	25	89	4	2	35	376
Bonaparte's Gull	9	5	43	42	28	0	9	0	3	0	39	178
Northern Gannet	35	6	12	4	14	18	14	0	0	1	7	111
Great Egret	10	0	1	3	3	1	6	3	0	0	69	96
Red-throated Loon	9	19	1	0	2	0	1	1	2	0	21	56
Gull-billed Tern	3	0	0	45	0	0	0	0	0	0	3	51
Red-breasted Merganser	1	0	0	0	0	0	0	16	0	0	21	38
Lesser Black-backed Gull	2	0	6	1	3	0	1	9	4	1	6	33
Great Blue Heron	1	0	1	6	5	0	1	1	0	0	17	32
Common Loon	6	1	2	1	4	0	1	3	0	1	3	22
Black Tern	20	0	0	0	0	0	0	0	0	0	0	20
Greater Scaup	0	0	0	0	0	0	0	0	0	16	0	16
Tricolored Heron	0	0	0	0	0	0	2	0	1	0	9	12
Snowy Egret	0	0	3	0	1	1	0	1	0	0	5	11
Glossy Ibis	0	0	0	1	1	0	0	0	0	0	7	9
Wood Stork	0	0	0	0	0	0	0	0	0	0	8	8
Horned Grebe	0	0	3	0	0	0	0	0	3	0	0	6
Great Cormorant	0	0	1	0	0	0	0	1	0	0	0	2

Table 2. (concluded)

	Transect #											
SPECIES	1	2	3	4	5	6	7	8	9	10	11	Grand Total
Sooty Tern	2	0	0	0	0	0	0	0	0	0	0	2
American Bittern	0	0	0	0	0	0	0	0	0	0	1	1
Arctic Tern	0	0	0	0	0	0	0	0	0	1	0	1
Black-cr. Night Heron	0	0	1	0	0	0	0	0	0	0	0	1
California Gull	0	0	0	0	0	0	0	1	0	0	0	1
Franklin's Gull	0	0	1	0	0	0	0	0	0	0	0	1
Glaucous Gull	1	0	0	0	0	0	0	0	0	0	0	1
Hooded Merganser	0	0	0	1	0	0	0	0	0	0	0	1
Little Blue Heron	0	0	0	0	0	0	0	0	0	0	1	1
Mew Gull	0	0	0	0	0	0	1	0	0	0	0	1
Sabine's Gull	1	0	0	0	0	0	0	0	0	0	0	1
Snow Goose	1	0	0	0	0	0	0	0	0	0	0	1
Total individuals	11,287	2,192	10,450	9,210	10,587	10,103	13,292	9,208	11,013	5,383	8,838	101,563
Total species	27	16	25	23	22	15	22	22	18	18	29	43

Table 3. Waterbird richness and abundance.

Site	Transect	Species	Average number of species/survey	Average number of birds/km/survey
Cape	1	**27**	**7.37**	**153.4**
Beach	2[a]	16	5.18	34.3
	5[a]	22	6.80	165.4
	6	15	6.00	157.9
	9[a,b]	18	6.08	114.7
	10	18	5.83	84.1
	13[a,c]	15	5.50	65.6
	Average	**17.3**	**5.90**	**103.7**
Inlet	3[a]	25	7.28	94.7
	4	23	7.58	95.9
	7	22	7.76	120.4
	8[b]	22	7.17	125.1
	11	29	9.13	60.0
	12[a,c]	26	8.39	137.4
	Average	**24.5**	**7.89**	**105.6**

[a] Renourished during 2001.
[b] Renourished during 2002.
[c] Transect at Ocean Isle.

Table 4. Most abundant waterbirds per survey per km (Transects #1 through 11).

Waterbird species	Cape	Beach	Inlet
Laughing Gull	18.6	48.2	23.7
Ring-billed Gull	11.8	37.1	15.7
Royal Tern	44.0	1.7	13.8
Brown Pelican	21.3	11.4	10.5
Herring Gull	14.6	5.9	6.7
Forster's Tern	11.2	4.2	5.8
Sandwich Tern	13.6	0.7	6.0
Double-crested Cormorant	7.4	0.6	4.4
Great Black-backed Gull	4.4	1.1	1.5
Black Skimmer	0.0	0.0	2.6

Table 5. Total numbers of shorebird individuals recorded for each species in each transect.

	Transect #											
SPECIES	1	2	3	4	5	6	7	8	9	10	11	Grand Total
Sanderling	796	339	1,589	787	387	450	1,155	452	705	558	851	8,069
Dunlin	0	0	533	394	0	0	1,926	762	0	11	1,172	4,798
Short-billed Dowitcher	0	0	405	252	6	4	1,313	445	8	32	577	3,042
Willet	228	144	366	85	145	151	405	153	147	285	246	2,355
Black-bellied Plover	12	5	494	336	15	26	503	321	48	84	396	2,240
Semipalmated Plover	19	3	5	8	20	0	884	207	3	10	356	1,515
Ruddy Turnstone	31	4	155	36	45	23	654	47	99	42	85	1,221
Killdeer	1	7	97	8	7	3	1	2	5	5	10	146
American Oystercatcher	8	1	0	1	4	3	93	0	0	11	12	133
Wilson's Plover	6	0	19	13	0	0	18	6	0	0	65	127
Semipalmated Sandpiper	1	0	0	0	36	9	4	1	0	0	31	82
Whimbrel	25	4	21	2	2	1	6	0	1	4	14	80
Piping Plover	1	1	0	26	0	0	0	2	0	0	20	50
Red Knot	9	0	7	1	0	8	10	0	0	1	9	45
Least Sandpiper	1	0	1	0	10	0	8	2	4	0	10	36
Western Sandpiper	5	3	0	0	4	0	5	5	0		4	26
Long-billed Dowitcher	0	0	2	4	0	0	4	0	0	0	0	10
Greater Yellowlegs	0	0	0	0	0	0	5	1	0	0	3	9
Spotted Sandpiper	0	0	1	0	0	0	1	0	1	0	2	5
Marbled Godwit	0	0	0	0	0	0	5	0	0	0	0	5
Pectoral Sandpiper	0	0	0	0	3	0	0	0	0	0	0	3
Lesser Yellowlegs	0	0	0	0	0	0	1	0	0	0	0	1
White-rumped Sandpiper	0	0	0	0	1	0	0	0	0	0	0	1
Total individuals	1,143	511	3,695	1,953	685	678	7,001	2,406	1,021	1,043	3,863	23,999
Total species	14	10	14	14	14	10	20	14	10	11	18	23

Table 6. Shorebird richness and abundance.

Site	Transect	Species	Average number of species/survey	Average number of birds/km/survey
Cape	1	**14**	**2.59**	**15.5**
Beach	2[a]	10	1.95	8.0
	5[a]	14	2.68	10.7
	6	10	2.28	10.6
	9[a,b]	10	2.83	10.6
	10	11	2.93	16.3
	13[a,c]	10	2.40	13.7
Avera			**2.51**	**11.7**
Inlet	3[a]	14	3.91	33.5
	4	14	3.40	20.3
	7	20	4.22	63.4
	8[b]	14	3.07	32.7
	11	18	4.78	26.2
	12[a,c]	22	4.43	22.9
Average			**3.97**	**33.2**

[a] Renourished during 2001.
[b] Renourished during 2002.
[c] Transect at Ocean Isle.

Table 7. Most abundant shorebirds per survey per km (Transects #1 through 11).

Waterbird species	Cape	Beach	Inlet
Sanderling	10.8	6.9	9.0
Willet	3.1	2.5	2.3
Dunlin	0.0	0.0	8.9
Short-billed Dowitcher	0.0	0.1	5.6
Black-bellied Plover	0.2	0.5	3.8
Semipalmated Plover	0.3	0.1	2.7
Ruddy Turnstone	0.4	0.6	1.8
Whimbrel	0.3	0.0	0.1
Killdeer	0.0	0.1	0.2
Semipalmated Sandpiper	0.0	0.1	0.1

Table 8. Percentage of total waterbird individuals recorded by habitat and transect.

Site	Transect	Intertidal	Beach	Dune
Cape	1	**78.5**	**19.6**	**1.9**
Beach	2[a]	73.0	10.5	16.5
	5[a]	55.7	29.6	14.7
	6	57.7	27.3	15.0
	9[a,b]	64.0	21.8	14.2
	10	57.6	20.4	22.0
	13[a,c]	40.1	33.5	26.4
Average		**58.0**	**23.9**	**18.1**
Inlet	3[a]	79.0	14.0	7.0
	4	89.0	3.9	7.1
	7	67.1	21.6	11.3
	8[b]	72.2	13.8	14.0
	11	85.4	7.1	7.5
	12[a,c]	87.5	7.1	5.4
Average		**80.0**	**11.3**	**8.7**

[a] Renourished during 2001.
[b] Renourished during 2002.
[c] Transect at Ocean Isle.

Table 9. Percentage of total shorebird individuals recorded by habitat and transect.

Site	Transect	Intertidal	Beach	Dune
Cape	1	**94.6**	**5.2**	**0.2**
Beach	2[a]	95.1	3.3	1.6
	5[a]	83.8	15.9	0.3
	6	80.1	18.4	1.5
	9[a,b]	86.6	13.1	0.3
	10	87.9	9.6	2.5
	13[a,c]	85.7	10.1	4.2
Average		**86.5**	**11.7**	**1.7**
Inlet	3[a]	73.2	26.5	0.3
	4	96.6	2.4	1.0
	7	54.8	44.9	0.3
	8[b]	80.6	18.7	0.7
	11	69.6	27.6	2.8
	12[a,c]	84.0	15.3	0.7
Average		**76.5**	**22.6**	**1.0**

[a] Renourished during 2001.
[b] Renourished during 2002.
[c] Transect at Ocean Isle.

Table 10. Percentage of total waterbird individuals recorded by activity and transects.

Site	Transect	Resting	Feeding	Flying	Breeding
Cape	1	**55.9**	**7.4**	**36.7**	**0.0**
Beach	2[a]	26.8	11.9	61.3	0.0
	5[a]	51.1	7.3	41.6	0.0
	6	54.1	8.1	37.8	0.0
	9[a,b]	47.6	11.1	41.3	0.0
	10	42.8	8.1	49.1	0.0
	13[a,c]	27.0	10.0	63.0	0.0
Average		**41.6**	**9.4**	**49.0**	**0.0**
Inlet	3[a]	60.3	4.5	35.2	0.0
	4	57.4	6.6	36.0	0.0
	7	57.7	4.9	37.4	0.0
	8[b]	42.4	6.4	51.2	0.0
	11	49.1	7.5	43.4	0.0
	12[a,c]	64.6	6.1	29.3	0.0
Average		**55.3**	**6.0**	**38.8**	**0.0**

[a] Renourished during 2001.
[b] Renourished during 2002.
[c] Transect at Ocean Isle.

Table 11. Percentage of total shorebird individuals recorded by activity and transect.

Site	Transect	Resting	Feeding	Flying	Breeding
Cape	1	**11.3**	**76.2**	**12.4**	**0.1**
Beach	2[a]	9.6	75.7	14.7	0.0
	5[a]	11.4	75.7	12.6	0.3
	6	12.4	67.1	20.5	0.0
	9[a,b]	17.4	70.6	12.0	0.0
	10	16.8	69.5	13.7	0.0
	13[a,c]	13.0	60.2	26.8	0.0
Average		**13.4**	**69.8**	**16.7**	**0.1**
Inlet	3[a]	54.2	34.8	10.9	0.1
	4	60.6	31.4	7.7	0.3
	7	75.0	16.4	8.5	0.1
	8[b]	66.4	24.9	8.7	0.0
	11	55.8	27.6	16.5	0.1
	12[a,c]	34.3	36.3	29.3	0.1
Average		**57.7**	**28.6**	**13.6**	**0.1**

[a] Renourished during 2001.
[b] Renourished during 2002.
[c] Transect at Ocean Isle.

Table 12. Signs of breeding birds along Transects 1 through 11, Brunswick County, N.C. during 2002.

Species	Island	location	Lat./Long.[a]	Transect	Comments
Killdeer	Bald Head	Cape Fear River	33° 86′ 23.94281″ N 78° 00′ 76.49710″ W	3E	Nest with 1 egg on 10 June. Nest with 3 eggs 17 June-2 July; bird on nest with 3 eggs on 26 June and 2 July. Nest empty and adult with 2 young out of study area on 12 July.
Wilson's Plover	Bald Head	Cape Fear River	33° 52′ 03.81020″ N 78° 00′ 36.02618″ W	3 E-M	Female with a less than one-week old chick seen on 19 July.
Wilson's Plover	Oak Island	Caswell Beach	33° 88′ 71.51449″ N 78° 01′ 95.69097″ W	4W-M	Nest with 3 eggs on 7-14 May. Two chicks seen on 28 May and 1 July. Three chicks seen with adults on 7 June, 18 June, and 25 June.
Wilson's Plover	Oak Island	Lockwood's Folly Inlet	33° 91′ 30.83890″ N 78° 22′ 96.16824″ W	7W-M	Birds defending territory on 28 May. Nest with 3 eggs on 7 June, female on nest with 3 eggs on 8 June.
Wilson's Plover	Holden Beach	Shallotte inlet	33° 90′ 70.34237″ N 78° 38′ 22.25875″ W	11W	Pair in dunes 8 May. Two adults with 2 chicks on 27 June.

[a] Nest locations or approximate nesting sites were determined with Trimble PRO XR GPS unit.

Table 13. Summary of recorded disturbances for each transect.

	Transect #										
Type of disturbance	1	2	3	4	5	6	7	8	9	10	11
Humans	38	36	38	25	36	38	44	43	39	35	43
Pets	11	14	8	5	7	7	15	6	8	2	10
Number of surveys	46	40	46	40	40	40	46	46	40	40	46
Average number of people per survey	16.11	21.75	9.22	4.83	47.70	38.45	45.74	41.74	71.63	62.10	34.93
Percent of surveys with a disturbance	82.61	90.00	82.61	62.50	90.00	95.00	95.65	93.48	97.50	87.50	93.48
Percent of disturbances with a pet	23.91	35.00	17.39	12.50	17.50	17.50	32.61	13.04	20.00	5.00	21.74

Table 14. Comparison of waterbird abundance (birds/km/survey) at high and low tide for cape, inlet, and beach transects during the 2002 monitoring period. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Transect	Mean low tide abundance (± SD)	Mean high tide abundance (± SD)	*p* value
Cape	**1**	**75.1 ± 76.7**	**286.8 ± 259.7**	**0.002**
Inlet	**3**	**53.5 ± 61.7**	**139.5 ± 118.6**	**0.006**
Inlet	**4**	**67.3 ± 82.3**	**127.6 ± 119.8**	**0.026**
Inlet	7	78.4 ± 92.9	162.4 ± 176.0	0.065
Inlet	8	128.3 ± 145.4	119.6 ± 110.3	0.946
Inlet	11	39.57 ± 33.93	80.5 ± 93.2	0.240
Beach	2	25.9 ± 15.1	43.5 ± 31.6	0.068
Beach	5	143.0 ± 83.4	185.7 ± 208.4	0.860
Beach	6	129.2 ± 75.7	186.6 ± 185.4	0.433
Beach	9	115.5 ± 67.5	113.9 ± 64.6	0.828
Beach	10	71.4 ± 55.2	94.6 ± 55.7	0.196

Table 15. Comparison of waterbird richness (species/km/survey) at high and low tide for cape, inlet, and beach transects during the 2002 monitoring period. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Transect	Mean low tide richness (± SD)	Mean high tide richness (± SD)	*p* value
Cape	**1**	**4.1 ± 1.3**	**5.4 ± 1.7**	**0.005**
Inlet	**3**	**2.8 ± 0.7**	**3.5 ± 1.2**	**0.019**
Inlet	4	3.0 ± 0.6	3.3 ± 0.8	0.198
Inlet	7	3.1 ± 0.9	3.4 ± 1.0	0.415
Inlet	8	4.5 ± 1.3	4.4 ± 1.2	0.936
Inlet	11	2.7 ± 0.8	3.0 ± 0.8	0.368
Beach	2	3.0 ± 0.9	3.5 ± 1.2	0.161
Beach	5	4.1 ± 0.9	4.4 ± 1.5	0.704
Beach	6	3.9 ± 1.1	3.6 ± 1.1	0.525
Beach	9	2.7 ± 0.8	2.3 ± 0.7	0.098
Beach	10	3.6 ± 1.2	3.7 ± 1.1	0.713

Table 16. Comparison of shorebird abundance (birds/km/survey) at high and low tide for cape, inlet, and beach transects during the 2002 monitoring period. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Transect	Mean low tide abundance (± SD)	Mean high tide abundance (± SD)	*p* value
Cape	1	14.1 ± 12.5	17.2 ± 11.2	0.365
Inlet	**3**	**11.9 ± 15.6**	**56.4 ± 74.7**	**0.005**
Inlet	**4**	**7.5 ± 7.8**	**34.2 ± 38.0**	**0.008**
Inlet	7	36.4 ± 59.7	85.1 ± 130.2	0.199
Inlet	**8**	**10.0 ± 11.6**	**71.4 ± 111.0**	**0.026**
Inlet	**11**	**8.5 ± 7.3**	**44.4 ± 54.4**	**< 0.001**
Beach	2	9.5 ± 10.1	6.4 ± 5.9	0.273
Beach	5	9.1 ± 8.1	12.2 ± 10.8	0.336
Beach	6	13.3 ± 10.9	7.9 ± 6.0	0.058
Beach	9	11.6 ± 6.7	9.6 ± 9.1	0.208
Beach	**10**	**12.1 ± 10.0**	**19.8 ± 11.5**	**0.031**

Table 17. Comparison of shorebird richness (species/km/survey) at high and low tide for cape, inlet, and beach transects during the 2002 monitoring period. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Transect	Mean low tide richness (± SD)	Mean high tide richness (± SD)	*p* value
Cape	1	1.5 ± 0.9	1.8 ± 0.6	0.071
Inlet	3	1.4 ± 0.6	1.8 ± 0.8	0.070
Inlet	**4**	**1.2 ± 0.5**	**1.7 ± 0.8**	**0.025**
Inlet	7	1.5 ± 0.8	2.0 ± 1.1	0.083
Inlet	8	1.7 ± 1.0	2.3 ± 1.4	0.198
Inlet	**11**	**1.2 ± 0.6**	**1.9 ± 0.7**	**<0.001**
Beach	2	1.4 ± 0.7	1.0 ± 0.5	0.069
Beach	5	1.5 ± 0.7	1.8 ± 1.2	0.434
Beach	**6**	**1.8 ± 0.8**	**1.1 ± 0.6**	**0.004**
Beach	9	1.2 ± 0.6	1.1 ± 0.4	0.957
Beach	**10**	**1.5 ± 0.8**	**2.1 ± 0.8**	**0.047**

Table 18. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of waterbirds. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	-18.22	-35.22	0.368	0.050
5	Beach	27	47	45.62	103.90	No test [b]	
6	Beach	37	40	30.17	73.75	No test [b]	
9	Beach	41	36	17.84	22.59	0.810 [a]	

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.

Table 19. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for richness of waterbirds. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	-0.418	0.345	0.082	0.287
5	**Beach**	**27**	**47**	**-0.07**	**0.63**	**0.020**	**0.561**
6	**Beach**	**37**	**40**	**-0.54**	**0.11**	**0.014** [a]	
9	**Beach**	**41**	**36**	**-0.05**	**-1.20**	**<0.001**	**0.999**

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.

Table 20. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of laughing gulls. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	-11.89	-18.84	No test [b]	
5	**Beach**	**27**	**47**	**6.20**	**55.65**	**0.040** [a]	
6	Beach	37	40	5.47	28.00	0.657 [a]	
9	**Beach**	**41**	**36**	**8.46**	**30.54**	**0.018** [a]	

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.

Table 21. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of royal terns. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	**Beach**	**18**	**20**	**.01**	**0.38**	**0.042** [a]	
5	Beach	27	47	0.09	2.57	0.124 [a]	
6	**Beach**	**37**	**40**	**-0.42**	**0.88**	**0.012** [a]	
9	Beach	41	36	-0.50	0.42	0.490 [a]	

[a] Compared using Wilcoxon Rank sum test

Table 22. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of brown pelicans. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	-3.1	-0.5	No test [b]	
5	Beach	27	47	-0.2	10.6	0.095 [a]	
6	Beach	37	40	2.4	7.6	0.561 [a]	
9	Beach	41	36	0.2	9.1	0.061 [a]	

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.

Table 23. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of ring-billed gulls. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	-22.4	-22.4	No test [b]	
5	Beach	27	47	40.8	21.6	No test [b]	
6	Beach	37	40	22.7	32.0	No test [b]	
9	**Beach**	**41**	**36**	**6.9**	**27.11**	**0.002**	**0.889**

[b] No test performed because data did not meet the test assumptions.

Table 24. Comparison of waterbird and shorebird abundance (birds/km/survey) at high and low tide before and after beach renourishment. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Mean low tide abundance (mean ± SD)	Mean high tide abundance (mean ± SD)	ANOVA interaction *p* value
Waterbirds			
Transect 2			
Before	57.4 ± 126.2	16.6 ± 10.9	0.105
After	29.6 ± 14.2	51.2 ± 32.6	
Transect 5			
Before	106.9 ± 54.5	114.5 ± 43.8	0.419
After	252.4 ± 367.0	181.1 ± 195.9	
Transect 6			
Before	95.9 ± 41.7	102.7 ± 48.8	0.566
After	129.2 ± 75.7	186.6 ± 185.4	
Transect 9			
Before	109.7 ± 60.2	76.1 ± 35.6	0.093
After	103.1 ± 51.1	113.9 ± 64.6	
Shorebirds			
Transect 2			
Before	1.7 ± 1.2	2.3 ± 2.0	0.165
After	6.3 ± 4.6	3.6 ± 4.3	
Transect 5			
Before	10.4 ± 10.2	8.0 ± 11.4	0.222
After	8.4 ± 7.6	11.8 ± 10.4	
Transect 6			
Before	11.3 ± 13.4	9.8 ± 8.1	0.389
After	13.3 ± 10.9	7.9 ± 6.0	
Transect 9			
Before	18.9 ± 15.0	13.3 ± 12.7	0.611
After	12.5 ± 6.5	9.6 ± 9.1	

Table 25. Comparison of laughing gull and royal tern abundance (birds/survey) at high and low tide before and after beach renourishment. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Mean low tide abundance (mean ± SD)	Mean high tide abundance (mean ± SD)	ANOVA interaction *p* value
Laughing Gull [a]			
Transect 2			
Before	No test[b]	No test	
After	No test	No test	
Transect 5			
Before	54.4 ± 43.3	104.8 ± 39.1	0.652
After	165.0 ± 216.7	164.1 ± 240.3	
Transect 6			
Before	62.2 ± 37.5	85.2 ± 58.4	0.964
After	121.6 ± 97.0	141.6 ± 226.2	
Transect 9			
Before	88.8 ± 82.0	53.8 ± 52.6	
After	123.6 ± 97.9	138.0 ± 96.5	0.251
Royal Terns [a]			
Transect 2			
Before	No test[b]	No test	
After	No test	No test	
Transect 5			
Before	2.0 ± 2.1	3.4 ± 5.1	0.377
After	4.6 ± 4.5	12.5 ± 22.0	
Transect 6			
Before	1.5 ± 2.1	1.4 ± 2.1	0.865
After	4.3 ± 4.9	3.8 ± 7.2	
Transect 9			
Before	1.2 ± 1.5	1.0 ± 1.8	0.465
After	3.4 ± 5.2	1.8 ± 4.6	

[a] December through February surveys not included due to the seasonal reduction of individuals.
[b] No test due to insufficient sample size in the pre-nourishment period.

Table 26. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of shorebirds. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys				*p* value	Power
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$		
2	Beach	18	20	-14.69	-9.436	No test[b]	
5	Beach	27	47	-10.34	-8.57	No test[b]	
6	Beach	37	40	-12.97	-5.70	0.403 [a]	
9	Beach	41	36	-7.80	-6.17	0.971 [a]	

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.

Table 27. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for richness of shorebirds. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys				*p* value	Power
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$		
2	Beach	18	20	-0.172	-0.53	0.254 [a]	
5	Beach	27	47	-0.14	-0.39	0.445 [a]	
6	Beach	37	40	-0.35	-0.41	0.624 [a]	
9	**Beach**	**41**	**36**	**-0.30**	**-0.64**	**0.029** [a]	

[a] Compared using Wilcoxon Rank sum test

Table 28. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of willet. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys				*p* value	Power
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$		
2	Beach	18	20	-2.13	-2.50	0.250	0.086
5	Beach	27	47	-2.73	-2.42	No test [b]	
6	Beach	37	40	-1.84	-2.09	No test [b]	
9	Beach	41	36	-1.78	-2.31	0.911 [a]	

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.

Table 29. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of sanderling. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ ($\alpha = 0.05$).

Beach transects		Number of surveys				*p* value	Power
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$		
2	Beach	18	20	-5.80	-5.47	No test [b]	
5	Beach	27	47	-3.89	-3.46	0.412 [a]	
6	Beach	37	40	-4.41	-1.69	0.639 [a]	
9	Beach	41	36	-0.29	2.40	0.126 [a]	

[a] Compared using Wilcoxon Rank sum test
[b] No test performed because data did not meet the test assumptions.

Table 30. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of black-bellied plovers. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ (α = 0.05).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	NA [c]	NA		
5	Beach	27	47	NA	NA		
6	Beach	37	40	-0.14	-0.91	0.120 [a]	
9	Beach	41	36	-0.50	-0.59	No test [b]	

[a] Compared using Wilcoxon Rank sum test.
[b] No test performed because data did not meet the test assumptions.
[c] No test performed because individuals were present in less than five pre-nourishment survey weeks

Table 31. T-test comparisons of pre- and post-nourishment △ (renourished transect - control) for abundance of ruddy turnstones. P values in bold represent significant differences in $\triangle_b$ and $\triangle_a$ (α = 0.05).

Beach transects		Number of surveys					
Transect	Site	Before	After	$\triangle_b$	$\triangle_a$	*p* value	Power
2	Beach	18	20	NA [b]	NA		
5	Beach	27	47	-0.21	-0.13	0.698 [a]	
6	Beach	37	40	-0.54	-0.30	0.603 [a]	
9	Beach	41	36	0.00	0.67	0.222 [a]	

[a] Compared using Wilcoxon Rank sum test
[b] No test performed because individuals were present in less than five pre-nourishment survey weeks

Table 32. Comparison of willet and sanderling abundance (birds/survey) at high and low tide before and after beach renourishment. P values in bold represent significant differences ($\propto$ = 0.05).

Transect description	Mean low tide abundance (mean ± SD)	Mean high tide abundance (mean ± SD)	ANOVA interaction *p* value
Willet			
Transect 2			
Before	2.0 ± 1.4	1.2 ± 1.3	0.414
After	2.1 ± 3.6	3.8 ± 7.6	
Transect 5			
Before	2.2 ± 2.2	1.6 ± 2.7	0.152
After	2.5 ± 3.2	3.9 ± 3.0	
Transect 6			
Before	4.6 ± 5.6	3.9 ± 4.1	0.468
After	3.4 ± 3.0	4.2 ± 4.3	
Transect 9			
Before	5.5 ± 6.6	2.9 ± 3.3	0.852
After	5.0 ± 4.4	2.8 ± 1.7	
Sanderling[a]			
Transect 2			
Before	No test[b]	No test	
After	No test	No test	
Transect 5			
Before	24.2 ± 8.4	7.6 ± 8.2	**0.001**
After	11.3 ± 8.0	10.4 ± 6.0	
Transect 6			
Before	17.5 ± 14.0	13.6 ± 18.8	0.538
After	18.6 ± 14.0	11.0 ± 6.5	
Transect 9			
Before	24.6 ± 15.1	21.9 ± 18.4	0.937
After	22.5 ± 9.3	20.5 ± 20.1	

[a] December through March surveys not included due to the seasonal reduction of individuals.
[b] No test due to insufficient sample size in the pre-nourishment period.

Table 33. Summary of piping plover observations.

Transect #	Total observations	Transect segment				Habitat Use			Activity			
		East	East-middle	West	West-middle	Intertidal	Beach	Dune	Resting	Feeding	Flying	Breeding
1	1	0	0	1	0	1	0	0	0	1	0	0
2	1	0	0	0	1	1	0	0	0	1	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	26	0	0	14	12	18	8	0	7	17	2	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	2	0	0	0	2	0	0	2	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	20	14	3	3	0	15	5	0	4	16	0	0
12[a]	7	1	6	0	0	7	0	0	0	7	0	0
13[a]	0	0	0	0	0	0	0	0	0	0	0	0
Totals	57	15	11	18	13	42	15	0	11	44	2	0

[a] Transect at Ocean Isle.

Table 34. Summary of all waterbird data by transect.

Transect#	Island	Site	Total # Species	Total Individuals	Avg. # species/ survey	Avg. # individuals/ kilometer/ survey	Percentage of birds						
							Habitat Use			Activity			
							Intertidal	Beach	Dune	Resting	Feeding	Flying	Breeding
1	Bald Head	Cape Fear	27	11,287	7.37	152.5	78.5	19.6	1.9	55.9	7.4	36.7	0.0
2	Bald Head	South Beach	16	2,192	5.18	34.1	73.0	10.5	16.5	26.9	11.9	61.3	0.0
3	Bald Head	River Cape	25	10,450	7.28	94.1	79.0	14.0	6.9	60.3	4.5	35.2	0.0
4	Oak Island	Caswell	24	9,210	7.58	95.4	89.0	3.9	7.2	57.4	6.6	36.0	0.0
5	Oak Island	East Beach	22	10,587	6.80	164.5	55.7	29.6	14.7	51.1	7.3	41.7	0.0
6	Oak Island	West Beach	15	10,103	6.00	157.0	57.7	27.3	15.0	54.1	8.1	37.8	0.0
7	Oak Island	Lockwoods	22	13,292	7.76	119.7	67.2	21.6	11.3	57.6	4.9	37.4	0.0
8	Holden	Lockwoods	22	9,208	7.17	124.4	72.2	13.8	14.0	42.4	6.4	51.2	0.0
9	Holden	East Beach	18	11,013	6.08	171.1	64.0	21.8	14.2	47.7	11.1	41.3	0.0
10	Holden	West Beach	18	5,383	5.83	83.6	57.6	20.5	22.0	42.8	8.1	49.1	0.0
11	Holden	Shallotte Inlet	29	8,838	9.13	59.7	85.4	7.1	7.5	49.1	7.5	43.4	0.0
12	Ocean Isle	Shallotte Inlet	26	10,747	8.39	133.7	87.5	7.1	5.4	64.6	6.1	29.3	0.0
13	Ocean Isle	East Beach	15	4,197	5.50	65.2	40.2	33.5	26.4	27.0	10.0	63.0	0.0

Table 35. Summary of all shorebird data by transect.

Transect#	Island	Site	Total # Species	Total Individuals	Avg. # species/ survey	Avg. # individuals/ kilometer/ survey	Percentage of birds						
							Habitat Use			Activity			
							Intertidal	Beach	Dune	Resting	Feeding	Flying	Breeding
1	Bald Head	Cape Fear	14	1,143	2.59	15.4	94.6	5.2	0.2	11.3	76.2	12.4	0.1
2	Bald Head	South Beach	10	511	1.95	7.9	95.1	3.3	1.6	9.6	75.7	14.7	0.0
3	Bald Head	River Cape	14	3,695	3.91	33.3	73.2	26.5	0.3	54.2	34.9	10.9	0.1
4	Oak Island	Caswell	14	1,953	3.40	20.2	96.6	2.4	1.0	60.7	31.4	7.7	0.3
5	Oak Island	East Beach	14	685	2.68	10.6	83.8	15.9	0.3	11.4	75.8	12.6	0.3
6	Oak Island	West Beach	10	678	2.28	10.5	80.1	18.4	1.5	12.4	67.1	20.5	0.0
7	Oak Island	Lockwoods	20	7,001	4.22	63.0	54.8	44.9	0.3	75.1	16.4	8.5	0.1
8	Holden	Lockwoods	14	2,406	3.07	32.5	80.6	18.7	0.7	66.4	24.9	8.7	0.0
9	Holden	East Beach	10	1,021	2.83	15.9	86.6	13.1	0.3	17.4	70.5	12.0	0.0
10	Holden	West Beach	11	1,043	2.93	16.2	87.9	9.6	2.5	16.8	69.5	13.7	0.0
11	Holden	Shallotte Inlet	18	3,863	4.78	26.1	69.6	27.6	2.8	55.8	27.7	16.5	0.1
12	Ocean Isle	Shallotte Inlet	22	1,789	4.43	22.3	84.0	15.4	0.7	34.3	36.3	29.3	0.1
13	Ocean Isle	East Beach	11	874	2.40	13.6	85.7	10.1	4.2	13.0	60.2	26.8	0.0

APPENDICES

APPENDIX A

DESCRIPTIONS OF FEATURES AND COORDINATES ALONG TRANSECTS FOR BRUNSWICK COUNTY, NC BIRD SURVEYS

Appendix A. Descriptions of features and coordinates along transects for Brunswick County, NC bird surveys.

Transect ID[a]	Easting[b]	Northing[b]	Comments/visual aids
TRANSECT #1			
Bald Head - Cape Fear			1 mile long
East end	2315917.115	37794.761	near crossover beach access at the Gazebo
Quarter point	2315799.149	36479.353	near solitary palmetto tree along edge of woods
Mid point	2315540.251	35185.189	On E. beach, in line w/ S. facing dune line and brown house w/ large white brick chimney
Cape Fear	2315502.197	34940.807	"point" of Cape Fear
Three-quarter point	2314612.111	35539.977	approx. 50' W. of clump of large root debris; overturned steps in dunes
West end	2313514.174	36272.671	Beach access at Capt. Charlie's crossover
TRANSECT #2			
Bald Head - South Beach			1 mile long
East end	2310184.548	37794.124	between beach crossovers (one near Killagray Ridge intersection); 2 A-frame w/chimneys
Quarter point	2308955.866	38276.389	vacant lot; house to W. has 2 ship windows; 310' E of beach access w/ life ring
Mid point	2307722.351	38746.510	near intersection of Sea Holly Ct.; 400' E. of house close to beach
Three-quarter point	2306474.703	39177.349	approx. 50 yards W. of large arch window; near tire in dune
West end	2305223.402	39597.850	Beach access at west end of Sandspur Rd.
TRANSECT #3			
Bald Head - West Beach			1.5 miles long
Southeast end	2302167.954	41532.225	Near beige beach rentals (Bald Head Island Villa); just past pond
	2301723.378	41920.273	
	2301233.437	42406.069	
Quarter point	2300893.137	43017.688	near gray "shuttered" house near end of zig-zag sand fence
	2300366.222	44200.784	
Mid point	2300800.229	44743.656	2 story house with catwalk/wind meter; between houses w/ flagpoles; N. end of tern area
	2301206.938	44987.956	
	2301450.946	45230.838	
	2301844.899	45440.544	
Three-quarter point	2302244.298	46036.515	approx. 200' N. of 1st house from 1st beach access (Green Turtle)
Northwest end	2303057.386	47842.365	Entrance to marina; metal pole next to breakwall

Appendix A. (continued)

Transect ID[a]	Easting[b]	Northing[b]	Comments/visual aids
TRANSECT #4			
Oak Island - Ft. Caswell			1.5 miles long
East end	2298161.812	54812.636	Last small house near end of breakwall; 3rd house N. of pier
	2298546.071	54674.907	
	2299134.678	53839.525	
Quarter point	2299346.409	53331.501	100 yards S. of large building along beach
	2299359.942	52895.648	
	2298978.014	51831.457	
Mid point	2298722.168	51507.045	In line with Old Baldy and tower on Assembly grounds; green buoy with house left of baldy
	2298308.477	51308.120	
	2297719.000	51280.710	
	2297232.524	51409.947	
Three-quarter point	2296852.943	51607.953	1980'from walkover; yuccas on ridge; log on high beach
West end	2295032.611	52388.352	Beach access at Assembly grounds guard gate
TRANSECT #5			
Oak Island - Middle East			1 mile long
East end	2278588.057	57260.419	Yaupon pier
Quarter point	2277329.469	57656.341	Peach house, 40' east of SE 79th st.
Mid point	2276028.260	57907.216	Green house, among group of four houses, with long walkway, satellite dish
Three-quarter point	2274742.483	58205.352	Between new house and beige house; 150' east of Beach st. and W. of gazebo
West end	2273444.058	58470.762	House with long walkway over marsh; 200' W. of 67th st.; 200' W. of beach access
TRANSECT #6			
Oak Island - Middle West			1 mile long
East end	2258839.339	60500.678	Ocean crest pier
Quarter point	2257528.304	60642.796	House #921; lt. green house w/asbestos siding, pelican in window
Mid point	2256208.705	60731.652	House # 601 w/2 solar panels, next to "Baker's Dozen"
Three-quarter point	2254889.443	60793.157	House #113 "Abbey Rd"; gray shingles, 2 story, across from Elk's lodge
West end	2253569.125	60828.156	Near W. 2nd Place beach access; next to gray house "Camp David CSA"
TRANSECT #7			
Oak Island - Lockwoods Folly			1.5 miles long
East end	2238581.724	60408.552	At 57th Place beach access

Appendix A. (continued)

Transect ID[a]	Easting[b]	Northing[b]	Comments/visual aids
Quarter point	2236609.499	60231.081	2nd house past lt. green house (2 story) w/ fish eye window in widow's peak
Mid point	2234648.298	59946.335	Last house on main road prior to parking lot; low 2 story w/ green top/white bottom
	2233704.061	59880.751	
Three-quarter point	2232749.937	60280.810	Between red buoy and last house (2 story)
	2232017.843	60702.416	
	2231850.942	61412.911	
	2232037.702	61500.375	
West end	2232013.673	61302.189	Past pole w/2 stripes near tip of cove
TRANSECT #8			
Holden Beach - Lockwoods Folly			1 mile long
East end	2231489.606	62508.131	Near red buoy; almost to back side of E. end of island
	2231371.256	61965.429	
Quarter point	2230848.562	61392.921	Between last house and gazebo
Mid point	2229586.288	61008.077	Near end of zig-zag sand fence; near W. gazebo; house w/ 3 A-peaks w/ arch window
Three-quarter point	2228297.130	60723.601	Between houses "Sand Dollars" and green cottage w/ red doors
West end	2226979.483	60648.555	Beach access at Ave. B
TRANSECT #9			
Holden Beach - Middle East			1.5 miles long
East end	2224424.004	60544.026	Beach access at ferry landing road
Quarter point	2222462.010	60282.046	Near beach condo #104
Mid point	2220492.793	60065.462	Just east of beige two-story house #1730
Three-quarter point	2218513.098	59950.469	Two houses east of house #257
West end	2216548.579	59686.574	West end of gray two-story house #321
TRANSECT #10			
Holden Beach - Middle West			1 mile long
East end	2205356.469	58424.860	House #767 (Adventure 3); E. of "keep off dunes" sign; 2 houses W. of "Great Place"
Quarter point	2204047.035	58249.901	Low yellow house (#823); W. of #821(low, vinyl house) on access steps
Mid point	2202739.038	58063.095	House # 875 (twin peak, A-frame, clapboard) across from Swordfish Dr.
Three-quarter point	2201433.066	57863.895	Low house with 3 palm trees; near pole in beach

Appendix A. (concluded)

Transect ID[a]	Easting[b]	Northing[b]	Comments/visual aids
West end	2200127.632	57661.255	House #981 (Bumble's Beach Cottage); 2 houses W. of red-shingled #977
TRANSECT #11			
Holden Beach - Shallotte Inlet			approximately 1.75 miles long
East end	2194460.587	56335.493	Beach crossing at Skimmer Ct.
Quarter point	2191903.624	55674.388	Double peach beach house w/ connecting breezeway
Mid point	2189304.121	56140.466	210' E. of new observation deck; due N. of red buoy #8
	2188404.891	56380.762	
	2187709.025	56817.187	
Three-quarter point	2187504.156	57683.904	In line w/ green and red buoys near inlet
	2187501.455	58194.300	
West end	2188025.854	58431.324	East side of small creek on back-side of island

[a]Transects were established with a Trimble Pro XRS GPS unit.
Transects were divided into four sections and identified in the field with red "pin flags" on the dune.
Each of the four segments for each transect are referred to as east, east-middle, west-middle, and west on the data form.
Unlabeled coordinates represent intermediate points established (but not identified in the field) to reflect a change in direction along the transect
[b]Coordinates are reported in North Carolina State Plane NAD 83 (feet).

APPENDIX B

SUMMARY OF SURVEY DATES OF ALL TRANSECTS

Appendix B. Summary of survey dates of all transects.

	Transect #										
WEEK #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
48	12-Dec-01	12-Dec-01	12-Dec-01	14-Dec-01	14-Dec-01	14-Dec-01	14-Dec-01	13-Dec-01	13-Dec-01	13-Dec-01	13-Dec-01
49	24-Dec-01	24-Dec-01	24-Dec-01	26-Dec-01	26-Dec-01	26-Dec-01	26-Dec-01	27-Dec-01	27-Dec-01	27-Dec-01	27-Dec-01
50	7-Jan-02	7-Jan-02	7-Jan-02	8-Jan-02	8-Jan-02	8-Jan-02	8-Jan-02	10-Jan-02	10-Jan-02	10-Jan-02	10-Jan-02
51	21-Jan-02	21-Jan-02	21-Jan-02	22-Jan-02	22-Jan-02	22-Jan-02	22-Jan-02	23-Jan-02	23-Jan-02	23-Jan-02	23-Jan-02
52	4-Feb-02	4-Feb-02	4-Feb-02	5-Feb-02	5-Feb-02	5-Feb-02	5-Feb-02	9-Feb-02	9-Feb-02	9-Feb-02	9-Feb-02
53	18-Feb-02	18-Feb-02	18-Feb-02	19-Feb-02	19-Feb-02	19-Feb-02	19-Feb-02	20-Feb-02	20-Feb-02	20-Feb-02	20-Feb-02
54	25-Feb-02	25-Feb-02	25-Feb-02	26-Feb-02	26-Feb-02	26-Feb-02	26-Feb-02	28-Feb-02	28-Feb-02	28-Feb-02	28-Feb-02
55	7-Mar-02	7-Mar-02	7-Mar-02	4-Mar-02	4-Mar-02	4-Mar-02	4-Mar-02	5-Mar-02	5-Mar-02	5-Mar-02	6-Mar-02
56	14-Mar-02	14-Mar-02	14-Mar-02	11-Mar-02	11-Mar-02	11-Mar-02	11-Mar-02	12-Mar-02	12-Mar-02	12-Mar-02	12-Mar-02
57	19-Mar-02	19-Mar-02	19-Mar-02	20-Mar-02	20-Mar-02	20-Mar-02	20-Mar-02	22-Mar-02	22-Mar-02	22-Mar-02	22-Mar-02
58	28-Mar-02	28-Mar-02	28-Mar-02	25-Mar-02	25-Mar-02	25-Mar-02	25-Mar-02	27-Mar-02	27-Mar-02	27-Mar-02	27-Mar-02
59	3-Apr-02	3-Apr-02	3-Apr-02	2-Apr-02	2-Apr-02	2-Apr-02	2-Apr-02	4-Apr-02	4-Apr-02	4-Apr-02	4-Apr-02
60	12-Apr-02	12-Apr-02	12-Apr-02	11-Apr-02	11-Apr-02	11-Apr-02	11-Apr-02	9-Apr-02	9-Apr-02	9-Apr-02	9-Apr-02
61	16-Apr-02	16-Apr-02	16-Apr-02	18-Apr-02	18-Apr-02	18-Apr-02	18-Apr-02	15-Apr-02	15-Apr-02	15-Apr-02	15-Apr-02
62	24-Apr-02	24-Apr-02	24-Apr-02	22-Apr-02	22-Apr-02	22-Apr-02	22-Apr-02	26-Apr-02	26-Apr-02	26-Apr-02	26-Apr-02
63	30-Apr-02	30-Apr-02	30-Apr-02	2-May-02	2-May-02	2-May-02	2-May-02	29-Apr-02	29-Apr-02	29-Apr-02	29-Apr-02
64	9-May-02	9-May-02	9-May-02	7-May-02	7-May-02	7-May-02	7-May-02	8-May-02	8-May-02	8-May-02	8-May-02
65	15-May-02	15-May-02	15-May-02	14-May-02	14-May-02	14-May-02	14-May-02	16-May-02	16-May-02	16-May-02	16-May-02
66	24-May-02	24-May-02	24-May-02	21-May-02	21-May-02	21-May-02	21-May-02	22-May-02	22-May-02	22-May-02	22-May-02
67	31-May-02	31-May-02	31-May-02	28-May-02	28-May-02	28-May-02	28-May-02	29-May-02	29-May-02	28-May-02	29-May-02
68	8-Jun-02		6-Jun-02				7-Jun-02	8-Jun-02			8-Jun-02
69	10-Jun-02		10-Jun-02				11-Jun-02	13-Jun-02			13-Jun-02
70	17-Jun-02		17-Jun-02				18-Jun-02	19-Jun-02			19-Jun-02
71	26-Jun-02		26-Jun-02				25-Jun-02	27-Jun-02			27-Jun-02
72	2-Jul-02		2-Jul-02				1-Jul-02	3-Jul-02			3-Jul-02
73	12-Jul-02		12-Jul-02				10-Jul-02	11-Jul-02			11-Jul-02
74	19-Jul-02	19-Jul-02	19-Jul-02	15-Jul-02	15-Jul-02	15-Jul-02	15-Jul-02	16-Jul-02	16-Jul-02	16-Jul-02	16-Jul-02
75	25-Jul-02	25-Jul-02	25-Jul-02	23-Jul-02	23-Jul-02	23-Jul-02	23-Jul-02	24-Jul-02	24-Jul-02	24-Jul-02	24-Jul-02
76	1-Aug-02	1-Aug-02	1-Aug-02	30-Jul-02	30-Jul-02	30-Jul-02	30-Jul-02	31-Jul-02	31-Jul-02	31-Jul-02	31-Jul-02
77	9-Aug-02	9-Aug-02	9-Aug-02	6-Aug-02	6-Aug-02	6-Aug-02	6-Aug-02	8-Aug-02	8-Aug-02	8-Aug-02	8-Aug-02
78	16-Aug-02	16-Aug-02	16-Aug-02	13-Aug-02	13-Aug-02	13-Aug-02	13-Aug-02	14-Aug-02	14-Aug-02	14-Aug-02	14-Aug-02
79	23-Aug-02	23-Aug-02	23-Aug-02	20-Aug-02	20-Aug-02	20-Aug-02	20-Aug-02	22-Aug-02	22-Aug-02	22-Aug-02	22-Aug-02
80	31-Aug-02	31-Aug-02	31-Aug-02	27-Aug-02	27-Aug-02	27-Aug-02	27-Aug-02	29-Aug-02	29-Aug-02	29-Aug-02	29-Aug-02
81	6-Sep-02	6-Sep-02	6-Sep-02	3-Sep-02	3-Sep-02	3-Sep-02	3-Sep-02	5-Sep-02	5-Sep-02	5-Sep-02	5-Sep-02

Appendix B. (concluded)

	Transect #										
WEEK #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
82	13-Sep-02	13-Sep-02	13-Sep-02	12-Sep-02	12-Sep-02	12-Sep-02	12-Sep-02	11-Sep-02	11-Sep-02	11-Sep-02	11-Sep-02
83	20-Sep-02	2-Sep-02	20-Sep-02	17-Sep-02	17-Sep-02	17-Sep-02	17-Sep-02	19-Sep-02	19-Sep-02	19-Sep-02	19-Sep-02
84	27-Sep-02	27-Sep-02	27-Sep-02	24-Sep-02	24-Sep-02	24-Sep-02	24-Sep-02	26-Sep-02	26-Sep-02	26-Sep-02	26-Sep-02
85	4-Oct-02	4-Oct-02	4-Oct-02	1-Oct-02	1-Oct-02	1-Oct-02	1-Oct-02	3-Oct-02	3-Oct-02	3-Oct-02	3-Oct-02
86	12-Oct-02	12-Oct-02	12-Oct-02	8-Oct-02	8-Oct-02	8-Oct-02	8-Oct-02	10-Oct-02	10-Oct-02	10-Oct-02	10-Oct-02
87	18-Oct-02	18-Oct-02	18-Oct-02	15-Oct-02	15-Oct-02	15-Oct-02	15-Oct-02	17-Oct-02	17-Oct-02	17-Oct-02	17-Oct-02
88	26-Oct-02	26-Oct-02	26-Oct-02	23-Oct-02	23-Oct-02	23-Oct-02	23-Oct-02	25-Oct-02	25-Oct-02	25-Oct-02	25-Oct-02
89	1-Nov-02	1-Nov-02	1-Nov-02	29-Oct-02	29-Oct-02	29-Oct-02	29-Oct-02	31-Oct-02	31-Oct-02	31-Oct-02	31-Oct-02
90	8-Nov-02	8-Nov-02	8-Nov-02	5-Nov-02	5-Nov-02	5-Nov-02	5-Nov-02	7-Nov-02	7-Nov-02	7-Nov-02	7-Nov-02
91	15-Nov-02	15-Nov-02	15-Nov-02	12-Nov-02	12-Nov-02	12-Nov-02	12-Nov-02	14-Nov-02	14-Nov-02	14-Nov-02	14-Nov-02
92	20-Nov-02	20-Nov-02	20-Nov-02	19-Nov-02	19-Nov-02	19-Nov-02	19-Nov-02	21-Nov-02	21-Nov-02	21-Nov-02	21-Nov-02
93	30-Nov-02	30-Nov-02	30-Nov-02	25-Nov-02	25-Nov-02	25-Nov-02	25-Nov-02	27-Nov-02	27-Nov-02	27-Nov-02	27-Nov-02

APPENDIX C

COMPLETED DATA SURVEY FORMS
(December 2001 through November 2002)

Appendix C is available for review and on file
with the Wilmington District Corps of Engineers
and CZR Incorporated

APPENDIX D

TOTAL NUMBER OF WATERBIRD SPECIES DURING EACH SURVEY BY TRANSECT

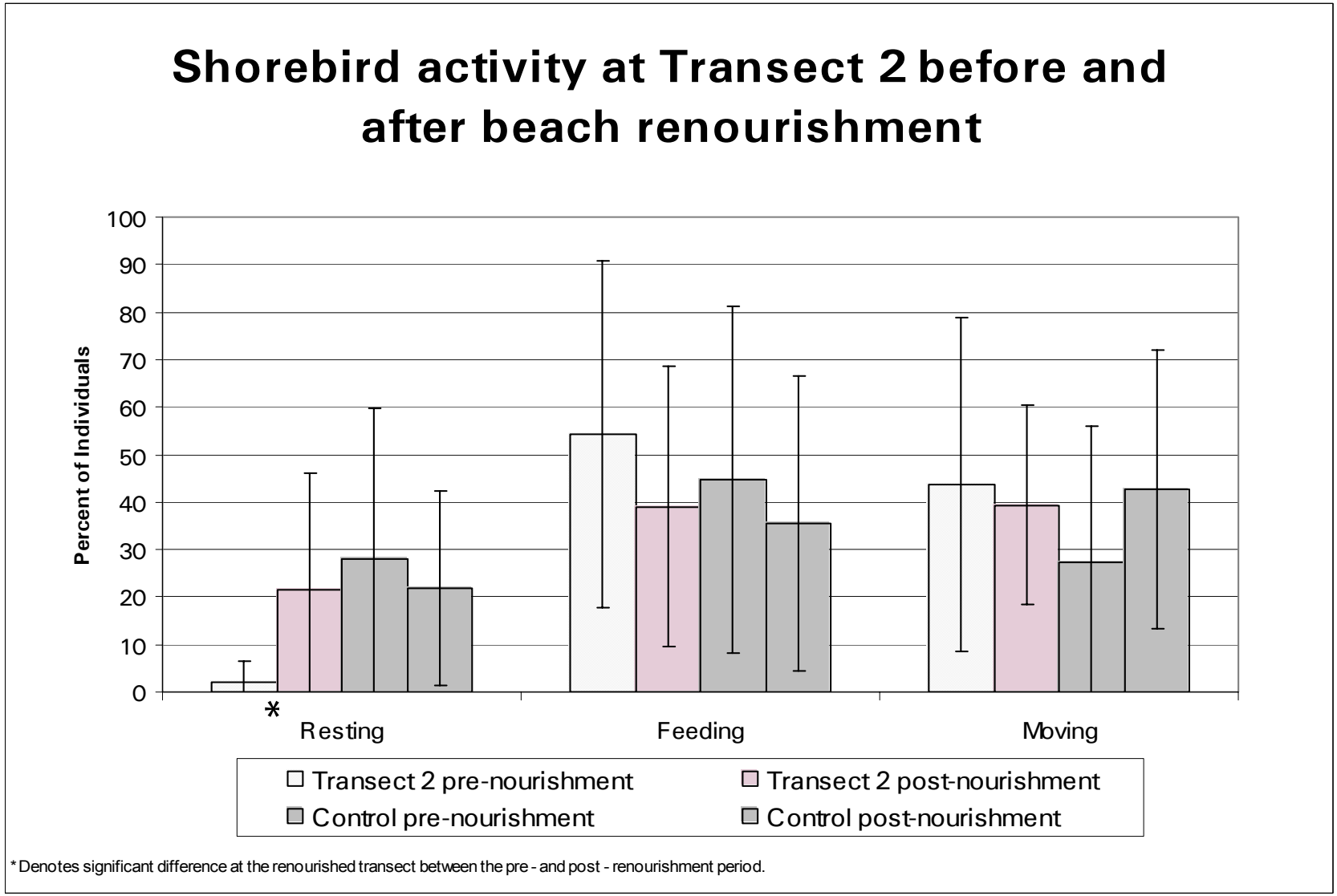


Figure 15. Shorebird activity (mean ± SD) at Transect 2 and the control during the pre - and post - renourishment period.

APPENDIX E

TOTAL NUMBER OF WATERBIRD INDIVIDUALS DURING EACH SURVEY BY TRANSECT

Appendix E. Total number of waterbird individuals during each survey by transect.

Week#	Transect #										
	1	2	3	4	5	6	7	8	9	10	11
48	45	73	567	310	144	160	75	50	708	135	78
49	89	83	530	130	589	179	66	156	240	100	98
50	158	54	76	78	169	373	255	97	140	61	56
51	259	199	803	427	299	252	134	81	527	123	39
52	28	61	448	53	207	708	159	65	167	87	66
53	711	20	443	97	118	512	64	104	302	134	105
54	110	47	107	137	232	150	89	77	112	52	91
55	32	84	104	1201	219	459	79	94	204	133	84
56	376	111	68	394	230	529	71	132	264	63	166
57	701	120	388	418	614	166	169	129	321	109	24
58	137	12	31	66	403	241	97	93	164	49	26
59	200	122	281	75	212	189	58	151	179	311	64
60	68	33	31	61	302	236	121	116	263	140	57
61	53	34	402	116	114	148	989	104	290	186	79
62	502	58	59	149	295	210	153	89	240	218	48
63	1289	51	446	134	197	137	57	88	302	186	47
64	63	42	112	133	148	167	196	279	148	92	49
65	50	54	93	89	255	70	67	57	210	131	35
66	137	24	66	132	81	62	45	62	191	109	57
67	358	45	83	134	124	190	159	88	135	35	85
68	84	-	79	-	-	-	106	50	-	-	110
69	314	-	188	-	-	-	312	149	-	-	168
70	151	-	424	-	-	-	62	193	-	-	133
71	46	-	460	-	-	-	508	304	-	-	128
72	20	-	81	-	-	-	201	334	-	-	210
73	113	-	71	-	-	-	166	266	-	-	216
74	44	49	61	428	233	74	79	713	302	240	117
75	826	29	39	93	340	335	474	123	293	310	145
76	19	27	1074	109	76	344	216	438	101	31	27

Week#	Transect #										
	1	2	3	4	5	6	7	8	9	10	11
77	481	50	285	96	267	79	60	79	120	52	133
78	50	25	48	502	175	99	147	406	249	114	40
79	278	31	130	31	118	336	109	54	162	35	86
80	82	61	269	893	160	212	929	305	89	186	161
81	34	4	20	50	62	59	262	165	502	28	45
82	26	18	781	635	40	33	743	412	88	217	490
83	59	28	37	69	48	154	157	80	181	227	340
84	25	32	367	317	152	314	462	162	438	269	757
85	24	10	20	67	171	183	163	340	394	194	163
86	48	31	464	131	370	260	583	1015	441	17	713
87	328	38	48	587	1483	340	553	57	186	370	464
88	1385	158	57	419	126	74	762	78	268	62	454
89	392	66	50	152	178	214	124	140	620	62	276
90	412	66	62	124	209	261	1792	64	155	80	425
91	72	29	54	71	185	95	92	56	240	24	37
92	531	95	82	20	337	154	1043	211	435	238	1174
93	77	18	61	82	905	1345	84	902	642	173	472
Total	11287	2192	10450	9210	10587	10103	13292	9208	11013	5383	8838
Average birds/ survey	245.37	54.80	227.17	230.25	264.68	252.58	288.96	200.17	275.33	134.58	192.13

"—" = no survey

APPENDIX F

TOTAL NUMBER OF WATERBIRD INDIVIDUALS PER SURVEY PER KM FOR YEARS 1 & 2

Appendix F. Total number of waterbird individuals per survey per km for years 1 and 2.

	Transect #										
SPECIES	1	2	3	4	5	6	7	8	9	10	11
Laughing Gull	16.13	19.17	23.50	15.35	67.06	57.42	32.25	34.40	43.10	34.86	13.81
Ring-billed Gull	14.47	9.78	16.51	7.30	50.35	52.95	18.78	18.75	36.95	25.42	10.94
Brown Pelican	24.05	7.58	7.79	12.13	15.28	14.69	12.32	15.04	10.67	8.89	8.55
Royal Tern	40.91	2.19	22.91	12.59	2.53	1.25	9.08	13.35	0.75	1.00	5.52
Herring Gull	13.26	2.15	6.37	8.47	7.31	6.89	8.18	6.28	5.70	4.04	5.74
Forster's Tern	6.44	2.71	5.40	2.18	5.73	4.47	7.48	4.98	4.92	2.10	6.67
Sandwich Tern	13.33	0.84	6.46	1.76	0.50	0.35	5.44	7.56	0.60	0.36	2.41
Double-crested Cormorant	4.65	0.77	0.97	24.06	0.56	0.64	0.60	4.51	0.35	0.71	1.16
Great Black-backed Gull	2.65	0.34	0.80	0.70	1.16	0.84	1.84	1.26	1.08	1.05	2.24
Black Skimmer	0.00	0.00	0.00	0.05	0.00	0.00	8.37	4.44	0.12	0.02	0.42
Common Tern	3.07	0.03	0.79	0.89	0.03	0.04	1.20	2.33	0.04	0.05	1.15
Caspian Tern	1.88	0.29	0.82	0.97	0.49	0.31	0.94	1.23	0.17	0.29	0.70
Bonaparte's Gull	0.89	5.08	0.47	0.27	0.25	0.32	0.50	0.09	1.29	0.93	0.16
Least Tern	2.81	0.22	1.38	0.25	0.08	0.02	0.28	1.81	0.06	0.05	0.23
White Ibis	0.04	0.09	1.53	0.60	0.35	0.02	0.00	0.00	0.05	0.00	1.51
Northern Gannet	1.07	0.15	0.22	0.15	0.26	0.24	0.12	0.13	0.15	0.20	0.03
Black Tern	0.34	0.00	0.03	0.00	0.00	0.00	0.00	0.66	0.01	0.00	0.02
Great Egret	0.07	0.00	0.01	0.03	0.02	0.01	0.03	0.03	0.00	0.00	0.26
Red-throated Loon	0.13	0.17	0.08	0.03	0.04	0.00	0.02	0.03	0.01	0.01	0.09
Red-breasted Merganser	0.01	0.00	0.00	0.07	0.00	0.00	0.01	0.11	0.00	0.00	0.20
Gull-billed tern	0.02	0.00	0.00	0.24	0.00	0.00	0.03	0.01	0.00	0.00	0.02
Yellow-crowned Night Heron	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00
Great Blue Heron	0.04	0.00	0.00	0.09	0.05	0.00	0.00	0.03	0.00	0.00	0.07
Glossy Ibis	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.05
Lesser Black-backed Gull	0.03	0.00	0.04	0.01	0.02	0.00	0.01	0.06	0.03	0.01	0.03
Common Loon	0.05	0.00	0.01	0.02	0.03	0.00	0.01	0.02	0.01	0.01	0.02
Black Scoter	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03
Snowy Egret	0.01	0.20	0.04	0.00	0.02	0.01	0.01	0.01	0.00	0.00	0.03
Tricolored Heron	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.04
Greater Scaup	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood Stork	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.04

Appendix F. (concluded)

	Transect #										
SPECIES	1	2	3	4	5	6	7	8	9	10	11
Horned Grebe	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01
Hooded merganser	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Little Blue Heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Surf Scoter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Great Cormorant	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.03	0.00
Mallard	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parasitic Jaeger	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sooty Tern	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
American Bittern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arctic Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black-crown Night Heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
California Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Franklin's Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glaucous Gull	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Greater Shearwater	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green Heron	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Iccland Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Mew Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pomarine Jaeger	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sabine's Gull	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snow Goose	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	146.40	51.78	96.17	88.26	152.15	140.46	107.84	117.16	106.09	80.14	62.16

APPENDIX G

TOTAL NUMBER OF SHOREBIRD SPECIES DURING EACH SURVEY BY TRANSECT

Appendix G. Total number of shorebird species during each survey by transect.

Week#	Transect #										
	1	2	3	4	5	6	7	8	9	10	11
48	1	1	2	6	2	2	3	2	3	4	2
49	1	3	4	3	1	2	4	1	2	3	3
50	3	2	6	1	2	0	1	3	2	0	1
51	1	1	3	5	2	1	5	2	2	4	2
52	2	1	6	2	1	0	8	2	1	1	1
53	2	1	6	5	2	2	7	1	2	3	6
54	1	1	2	1	1	2	1	6	3	2	0
55	1	1	1	4	2	1	7	5	3	2	2
56	2	2	1	0	1	1	2	6	2	2	2
57	4	1	2	5	3	0	10	3	2	3	9
58	2	2	1	2	1	0	2	5	3	0	2
59	1	1	4	8	2	2	4	3	2	3	8
60	3	1	3	6	2	4	3	4	2	2	2
61	3	1	4	5	2	2	4	1	3	4	3
62	4	2	3	2	2	3	3	3	3	3	5
63	3	2	6	4	3	1	5	2	2	2	5
64	2	2	4	2	2	2	6	3	2	2	6
65	6	4	2	2	4	3	3	2	2	4	6
66	6	2	3	4	2	4	3	2	3	2	5
67	4	1	4	3	4	4	5	2	3	3	10
68	2	-	2	-	-	-	5	0	-	-	5
69	2	-	4	-	-	-	2	1	-	-	3
70	0	-	2	-	-	-	2	1	-	-	3
71	1	-	3	-	-	-	1	3	-	-	7
72	1	-	2	-	-	-	1	2	-	-	3
73	2	-	4	-	-	-	2	1	-	-	4
74	2	2	3	2	0	1	1	3	1	1	2
75	2	1	5	4	2	2	5	2	2	2	7
76	2	2	4	3	2	2	2	4	4	2	4

Week#	Transect #										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
77	4	3	5	2	2	3	3	2	4	2	4
78	6	5	6	3	3	2	4	6	4	4	8
79	5	3	7	2	3	2	4	3	4	4	7
80	3	2	5	4	4	2	5	9	4	5	10
81	4	3	6	2	4	3	6	5	3	3	5
82	3	2	8	5	10	3	7	7	5	6	8
83	3	3	5	3	4	4	2	2	3	4	6
84	3	2	6	3	4	2	7	2	3	3	5
85	2	2	3	2	4	3	1	3	2	2	4
86	2	2	6	3	4	4	5	5	7	2	8
87	3	1	4	4	3	3	5	3	2	4	4
88	2	2	4	4	3	4	8	2	4	5	7
89	2	3	6	5	3	2	4	1	1	3	3
90	4	4	4	3	3	4	6	4	5	5	7
91	2	1	4	7	2	2	3	7	3	4	5
92	3	2	3	2	3	5	7	4	2	2	5
93	2	1	2	3	3	2	10	1	3	5	6
total	119	78	180	136	107	91	194	141	113	117	220
Average species/ survey	2.59	1.95	3.91	3.40	2.68	2.28	4.22	3.07	2.83	2.93	4.78

"—" = no survey

APPENDIX H

TOTAL NUMBER OF SHOREBIRD INDIVIDUALS DURING EACH SURVEY BY TRANSECT

Appendix H. Total number of shorebird individuals during each survey by transect.

Week#	Transect #										
	1	2	3	4	5	6	7	8	9	10	11
48	2	1	7	207	2	6	18	11	43	32	29
49	4	15	36	21	1	3	19	3	16	14	13
50	14	3	58	4	13	0	4	16	2	0	15
51	3	3	14	41	9	2	151	3	12	10	8
52	10	2	432	17	8	0	978	7	2	2	1
53	25	25	310	57	4	6	371	2	9	26	186
54	7	1	2	3	3	8	9	523	5	8	0
55	3	2	1	262	4	4	506	525	13	54	4
56	13	6	1	0	5	1	3	331	28	9	19
57	31	10	25	73	29	0	1242	6	3	23	729
58	15	8	1	2	6	0	18	25	8	0	9
59	4	1	54	75	4	4	156	12	14	37	476
60	13	5	10	264	5	21	13	15	5	10	16
61	15	1	18	51	9	19	172	25	15	64	33
62	25	9	5	26	13	14	38	14	6	31	28
63	36	6	275	51	25	7	207	29	7	18	22
64	21	14	32	9	12	11	40	17	19	8	24
65	97	24	27	16	14	66	35	23	82	77	80
66	31	13	21	42	17	17	22	10	55	23	40
67	17	4	7	22	45	42	15	2	19	9	80
68	6	-	6	-	-	-	38	0	-	-	19
69	36	-	11	-	-	-	9	2	-	-	9
70	0	-	7	-	-	-	11	3	-	-	18
71	5	-	12	-	-	-	1	11	-	-	79
72	1	-	2	-	-	-	1	5	-	-	12
73	22	-	19	-	-	-	9	3	-	-	31
74	16	11	8	4	0	11	4	9	1	9	6
75	11	2	36	8	11	10	42	6	30	24	87
76	25	9	89	37	9	20	12	72	21	13	47

Appendix H. (concluded)

Week#	Transect #										
	1	2	3	4	5	6	7	8	9	10	11
77	57	6	43	13	9	6	5	11	35	14	43
78	38	75	85	41	21	13	16	55	52	31	104
79	71	31	168	20	12	16	27	21	38	22	100
80	28	22	123	43	58	19	81	132	31	43	89
81	29	22	90	14	28	23	126	26	22	18	26
82	40	26	157	99	77	31	241	90	35	24	161
83	37	22	55	15	26	38	57	13	45	41	66
84	40	20	685	3	23	19	419	9	33	16	88
85	21	25	19	7	30	21	44	20	20	17	16
86	16	10	422	5	22	26	181	39	61	27	122
87	40	5	41	41	26	25	84	11	41	62	23
88	21	29	79	7	20	26	163	12	36	39	66
89	43	13	68	76	23	26	157	9	9	25	22
90	44	12	43	13	14	48	307	21	33	52	386
91	43	5	46	249	8	16	28	207	45	32	24
92	38	12	30	5	20	37	395	14	20	34	143
93	29	1	15	10	20	16	526	6	50	45	264
total	1143	511	3695	1953	685	678	7001	2406	1021	1043	3863
Average birds/ survey	24.85	12.78	80.33	48.83	17.13	16.95	152.20	52.30	25.53	26.08	83.98

"-" = no surveys

APPENDIX I

TOTAL NUMBER OF SHOREBIRD INDIVIDUALS PER SURVEY PER KM FOR YEARS 1 & 2

Appendix I. Total number of shorebird individuals per survey per km for years 1 & 2.

	Transect #										
SPECIES	1	2	3	4	5	6	7	8	9	10	11
Sanderling	9.05	4.33	11.41	9.74	5.77	6.87	9.42	6.68	8.88	10.12	5.93
Dunlin	0.00	0.00	2.66	7.95	0.02	0.00	12.31	5.56	0.00	0.12	6.00
Short-billed Dowitcher	0.07	0.00	2.76	2.82	0.05	0.05	7.37	3.14	0.06	2.95	4.59
Willet	2.94	1.74	3.01	0.83	1.80	2.52	4.88	2.20	2.00	4.47	1.87
Black-bellied Plover	0.15	0.12	3.04	4.41	0.25	0.57	3.47	2.53	0.56	1.23	2.73
Semipalmated Plover	0.22	0.02	0.08	0.20	0.60	0.03	5.56	1.65	0.04	0.22	3.10
Ruddy Turnstone	0.32	0.21	1.02	0.44	0.61	0.43	3.40	0.89	1.10	0.93	0.45
Semipalmated Sandpiper	0.03	0.03	0.00	0.04	0.39	0.07	0.02	0.73	0.15	0.00	0.35
Whimbrel	0.94	0.03	0.12	0.02	0.08	0.03	0.12	0.01	0.03	0.05	0.10
Killdeer	0.07	0.12	0.64	0.06	0.09	0.05	0.02	0.19	0.05	0.05	0.06
Wilson's Plover	0.15	0.02	0.19	0.08	0.00	0.00	0.17	0.07	0.01	0.01	0.31
American Oystercatcher	0.05	0.01	0.00	0.12	0.04	0.02	0.42	0.01	0.00	0.09	0.11
Piping Plover	0.07	0.01	0.01	0.27	0.03	0.00	0.01	0.06	0.00	0.02	0.13
Least Sandpiper	0.01	0.00	0.01	0.00	0.08	0.00	0.04	0.16	0.02	0.00	0.11
Red Knot	0.06	0.00	0.03	0.02	0.00	0.06	0.14	0.00	0.00	0.01	0.09
Western Sandpiper	0.04	0.02	0.00	0.08	0.03	0.00	0.02	0.03	0.00	0.00	0.01
Greater Yellowlegs	0.00	0.00	0.00	0.01	0.00	0.00	0.04	0.01	0.00	0.00	0.05
Long-billed Dowitcher	0.00	0.00	0.01	0.09	0.00	0.00	0.03	0.00	0.00	0.00	0.02
Marbled Godwit	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00
Pectoral Sandpiper	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01
Lesser Yellowlegs	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Spotted Sandpiper	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
Common Snipe	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solitary Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Buff-breasted Sandpiper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long-billed Curlew	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-rumped Sandpiper	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Totals	14.19	6.65	24.99	27.25	9.88	10.69	10.69	23.91	12.91	20.25	26.04

APPENDIX J

SUMMARY NOTES ON NESTING CHRONOLOGY OF BREEDING OR SUSPECTED BREEDING BIRDS ALONG TRANSECTS 1 THROUGH 11, BRUNSWICK COUNTY, NC

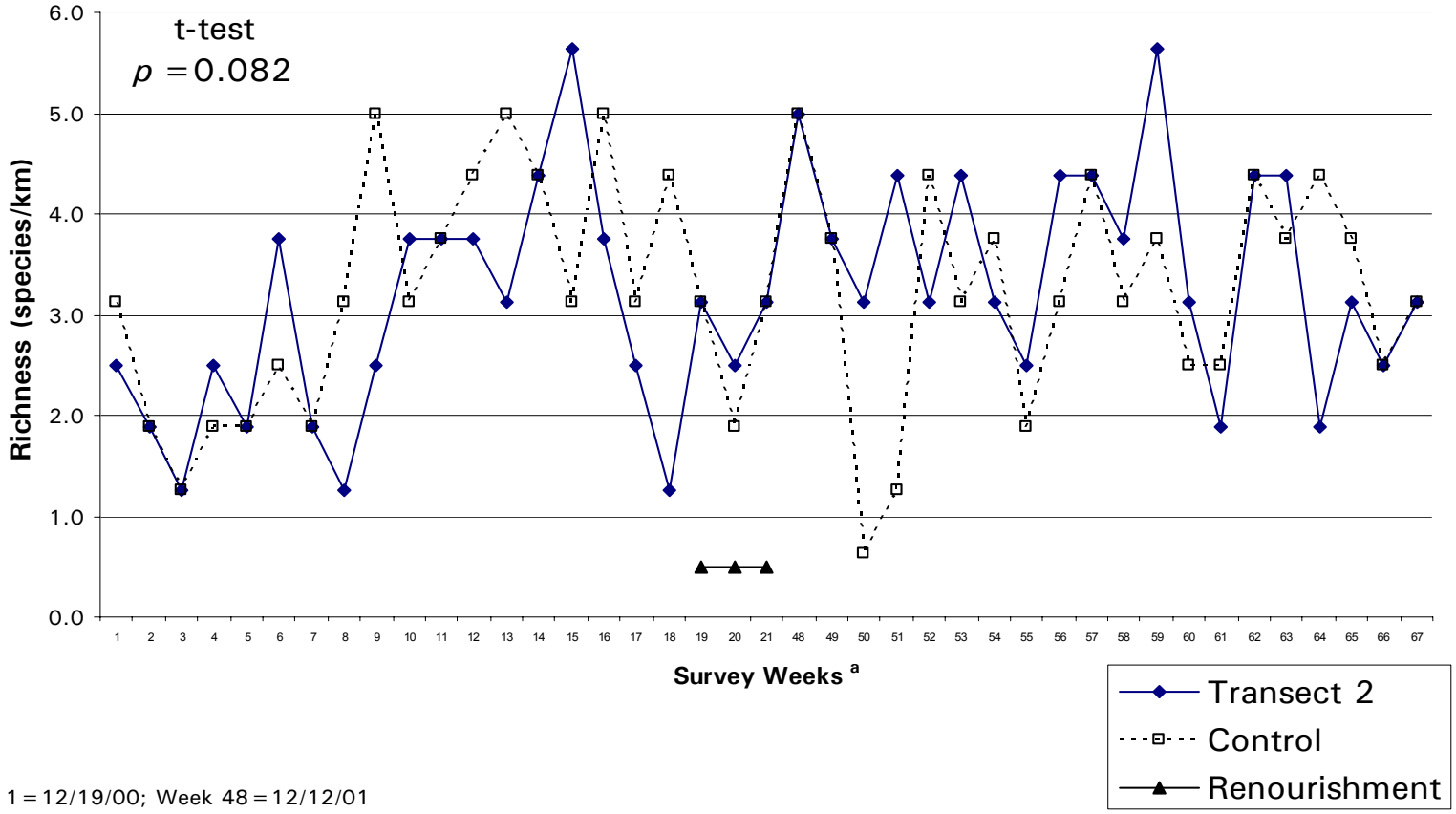
Appendix J. Summary notes on nesting chronology of breeding or suspected breeding birds along Transects 1 through 11, Brunswick County, NC.

Species	Island	Transect	Date	Courtship/displays	Eggs/nests	Young
Kildeer	Bald Head	3 E	10-Jun-02		Nest with 1 egg	
		3 E	17-Jun-02		Nest with 3 eggs	
		3 E	26-Jun-02		Female on nest with 3 eggs	
		3 E	2-Jul-02		Bird on nest with 3 eggs	
		3 E	12-Jul-02		Nest empty	Adult with 2 young seen just out of study area
Wilson's Plover	Bald Head	1 W-M	24-May-02	1 bird on territory		
Wilson's Plover	Bald Head	3 W-M	2-Jul-02	Female present		
		3 E-M	19-Jul-02			Female with 1 chick (<1 week old)
		3 E-M	25-Jul-02			Adult with 1 chick
Wilson's Plover	Caswell Beach	4 W-M	7-May-02		Nest with 3 eggs	
		4 W-M	14-May-02		Nest with 3 eggs	
		4 W-M	21-May-02		Nest empty-overwash	
		4 W-M	28-May-02			2 young with 2 adults in dune area
		4 W-M	7-Jun-02			Female with 3 chicks
		4 W-M	18-Jun-02			Male and female with 3 chicks
		4 W-M	25-Jun-02			Adult with 3 chicks
		4 W-M	1-Jul-02			Adult with 2 young
Wilson's Plover	Oak Island	7 W-M	28-May-02	Aggression between 2 males, 1 female present (1 dead male present)		
		7 W-M	7-Jun-02		Nest with 3 eggs	
		7 W-M	8-Jun-02		Female on nest with 3 eggs	
Wilson's Plover	Holden Beach	11 W-M	8-May-02	Pair on territory		
		11-W	27-Jun-02			2 adults with 2 chicks
		11 W-M	16-Jul-02			1 adult with 3 juveniles
Willet	Holden Beach	11 W-M	29-May-02	1 bird on territory		
		11-W	8-Jun-02	Pair suspected nesting in marsh outside study area		
		11-W	13-Jun-02	Pair suspected nesting in marsh outside study area		
Willet	Oak Island	7 E-M	18-Jun-02	Male on territory outside study area		

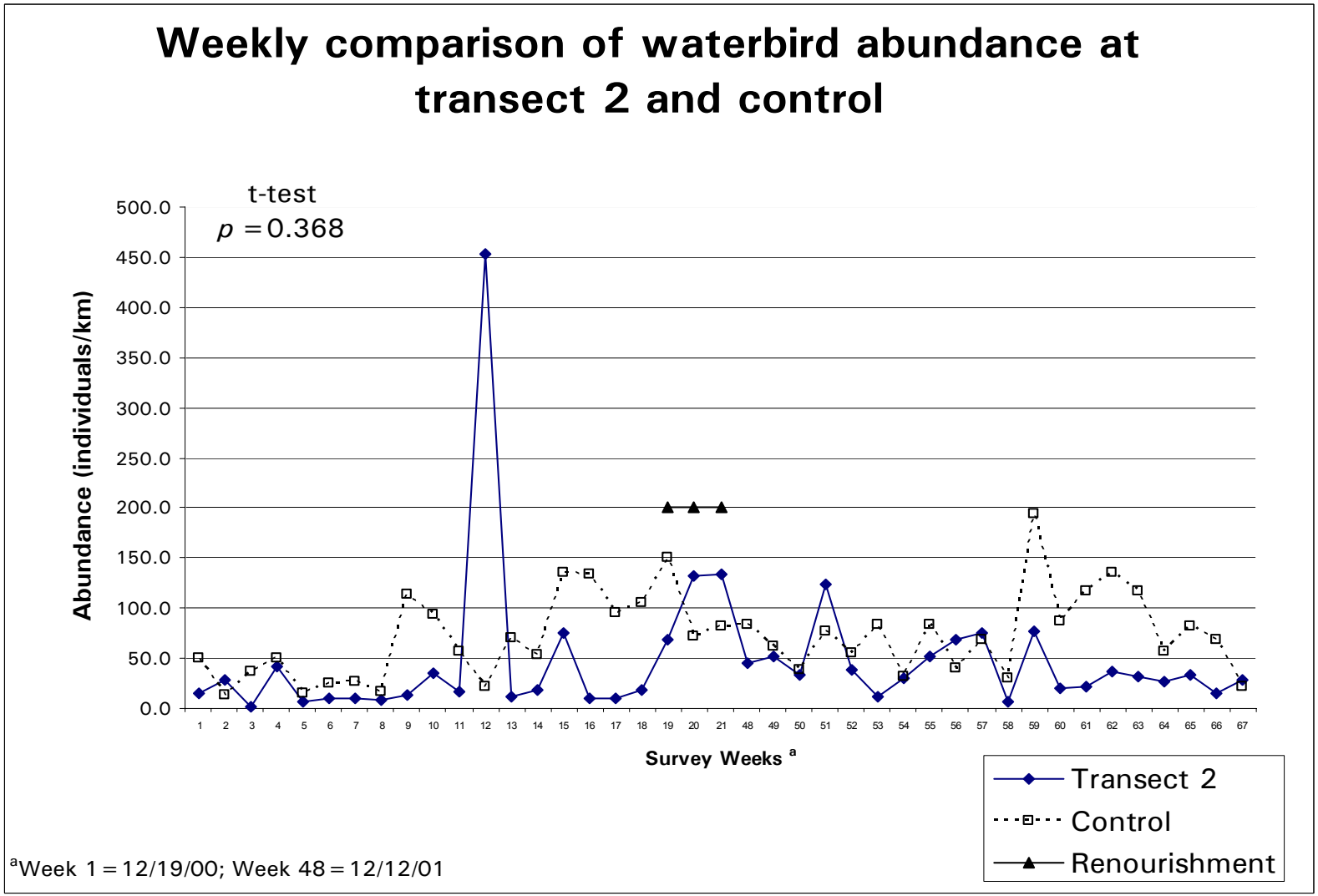
APPENDIX K

FIGURES DEPICTING WEEKLY WATERBIRD RICHNESS AND ABUNDANCE AT RENOURISHED TRANSECTS AND CONTROL AREAS

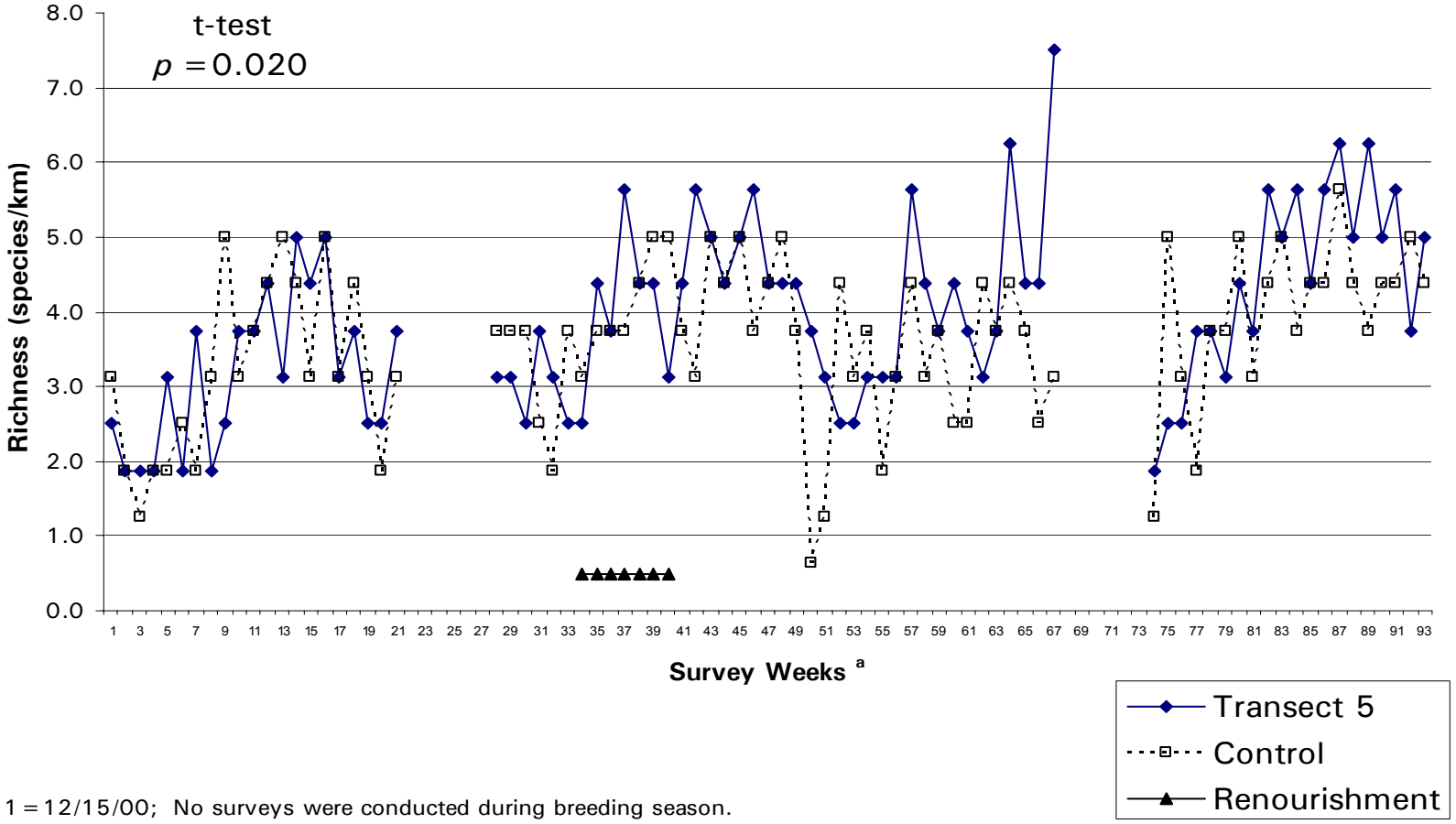
Weekly comparison of waterbird richness at transect 2 and control



[a]Week 1 = 12/19/00; Week 48 = 12/12/01

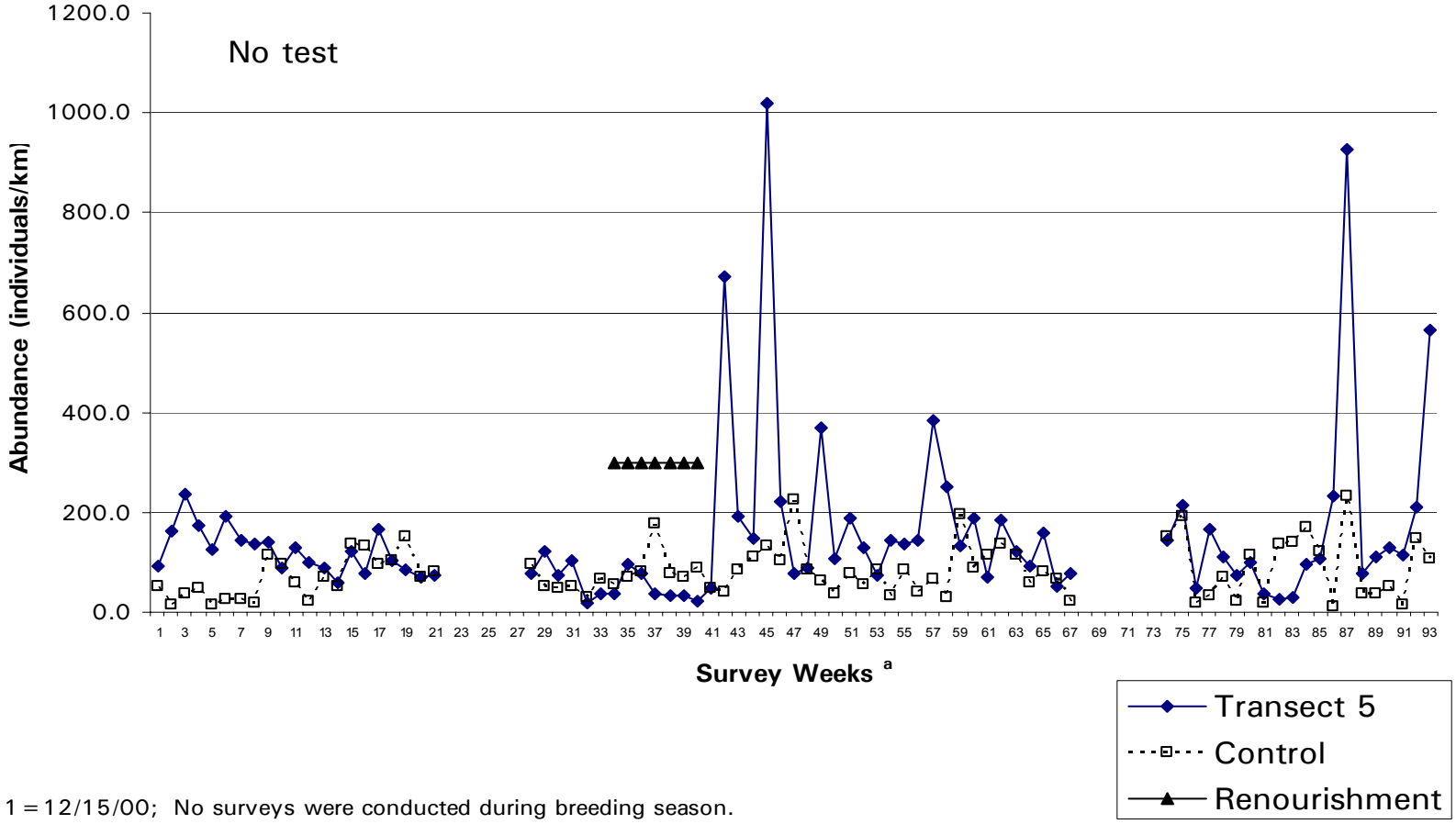

Weekly comparison of waterbird abundance at transect 2 and control
t-test
p = 0.368
Abundance (individuals/km)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67
Survey Weeks a
Transect 2
Control
Renourishment
aWeek 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of waterbird richness at transect 5 and control



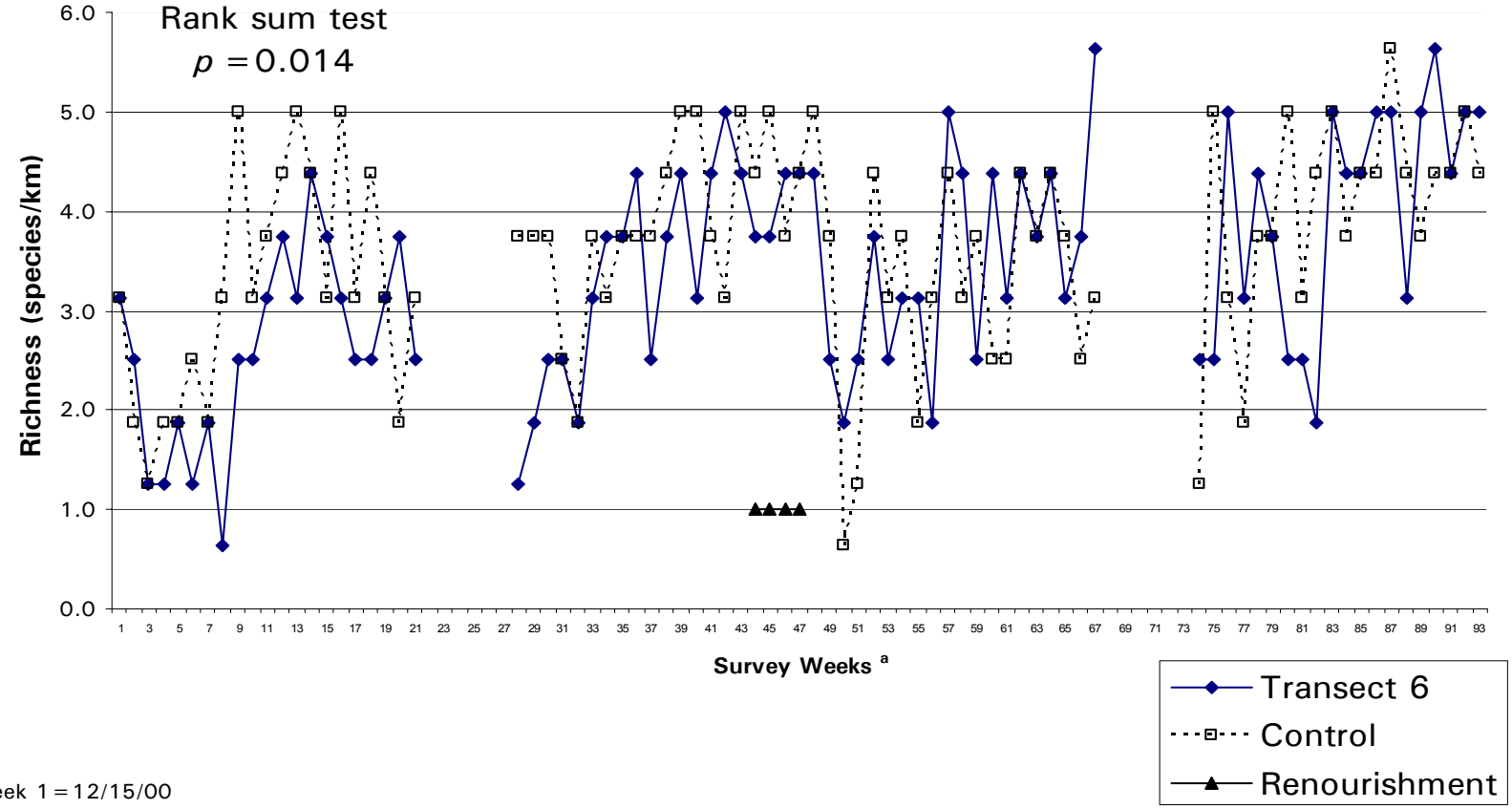
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of waterbird abundance at transect 5 and control



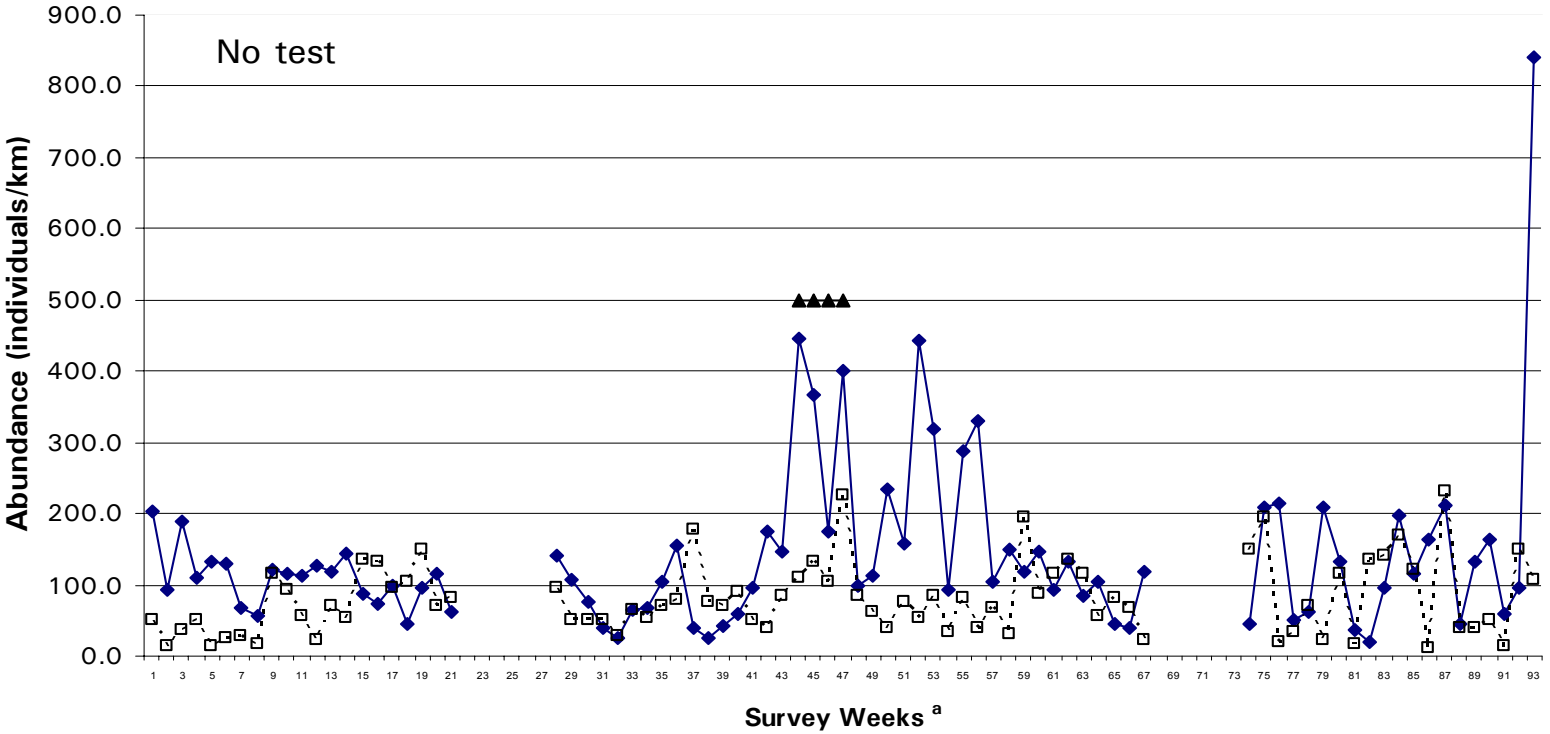
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of waterbird richness at transect 6 and control



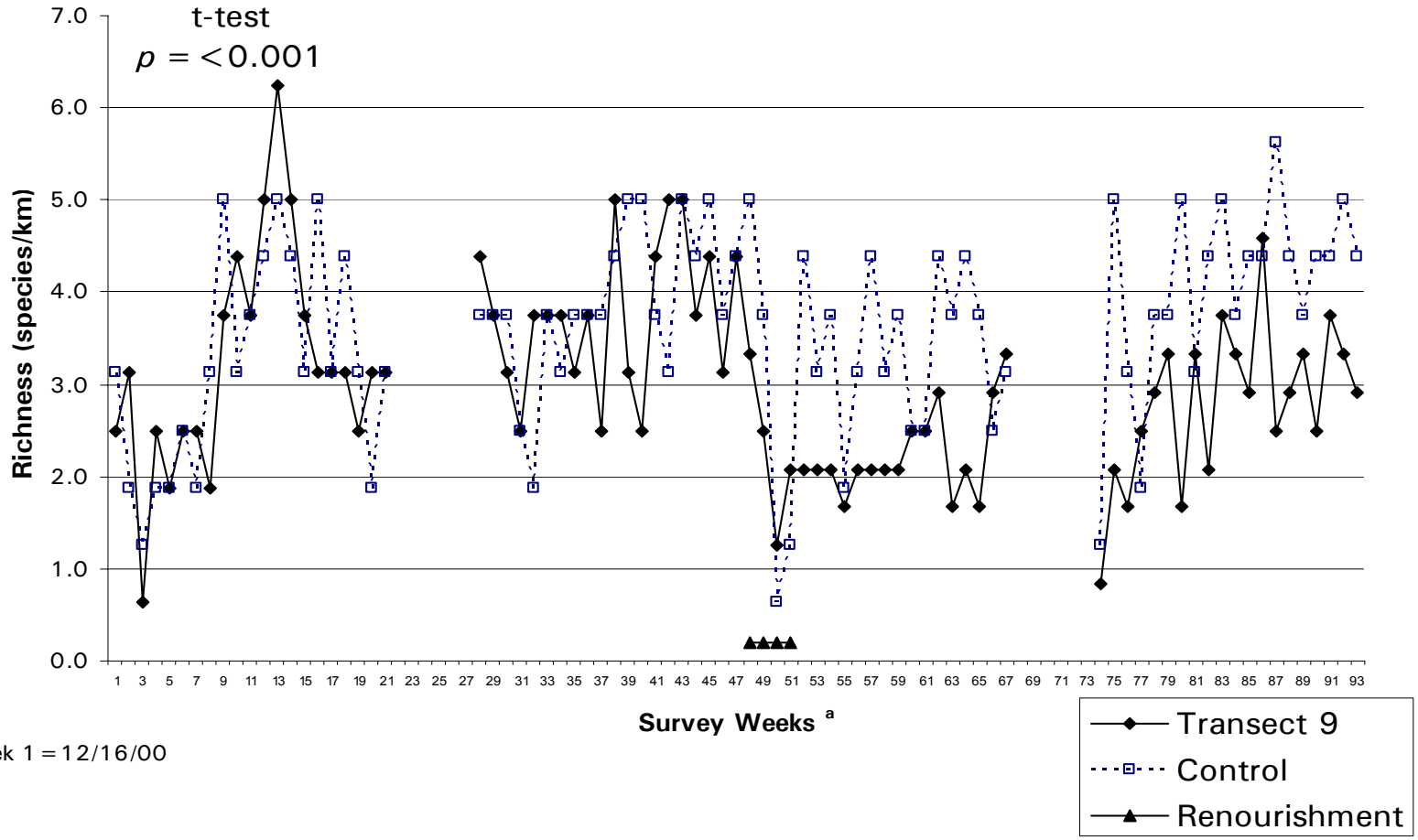
Week 1 = 12/15/00

Weekly comparison of waterbird abundance at transect 6 and control



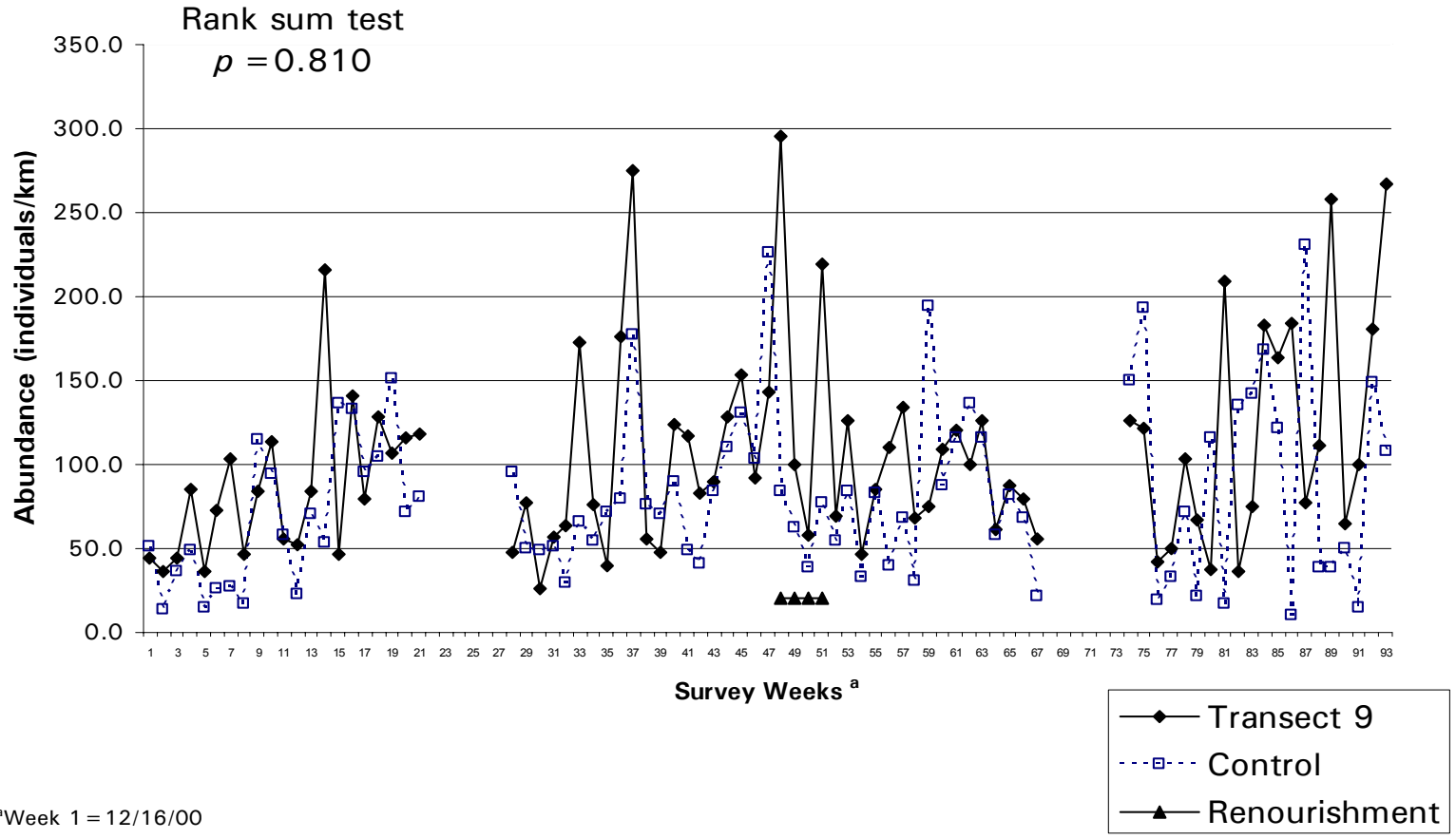
[a] Week 1 = 12/15/00

Weekly comparison of waterbird richness at transect 9 and control



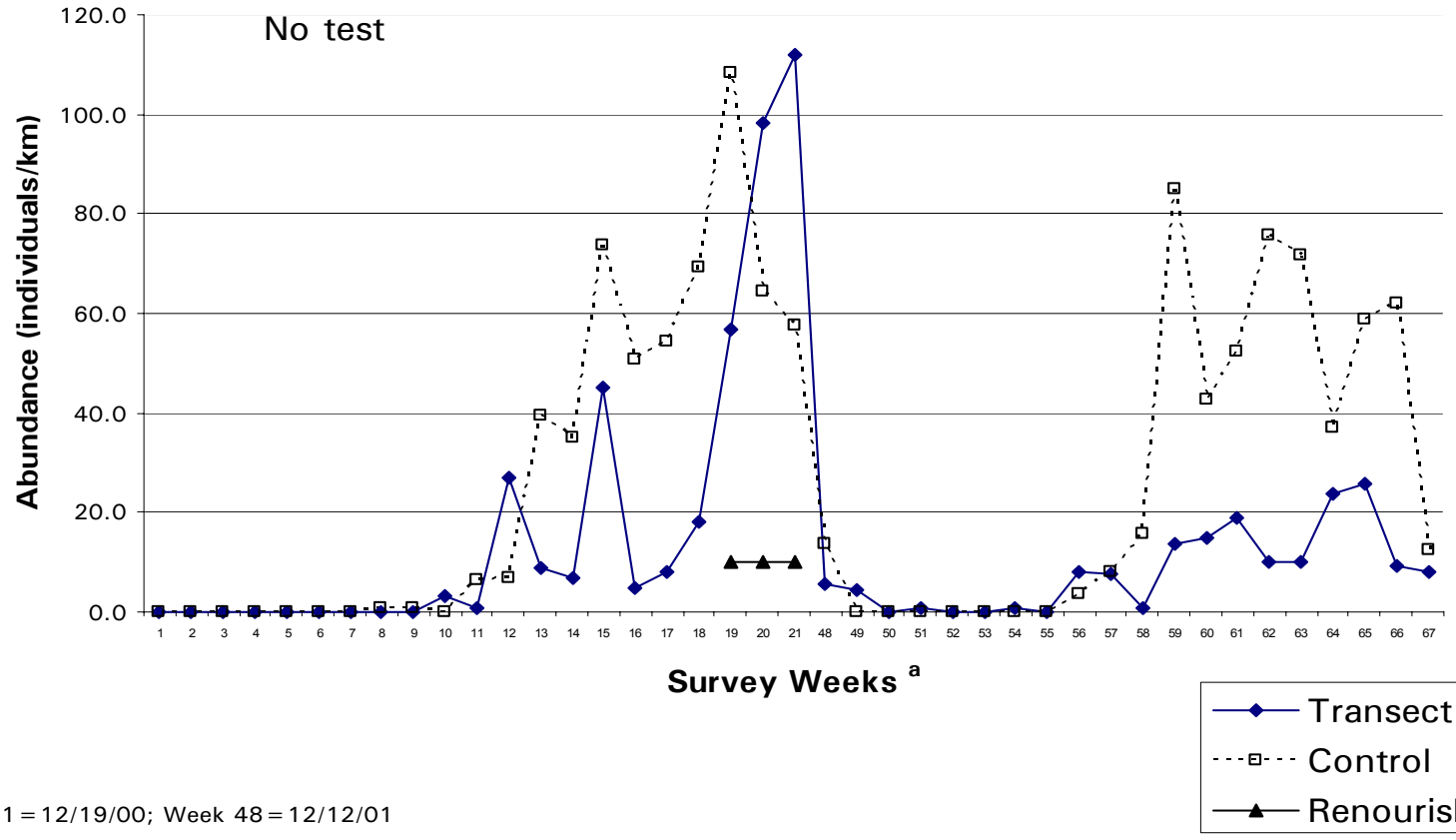
[a] Week 1 = 12/16/00

Weekly comparison of waterbird abundance at transect 9 and control



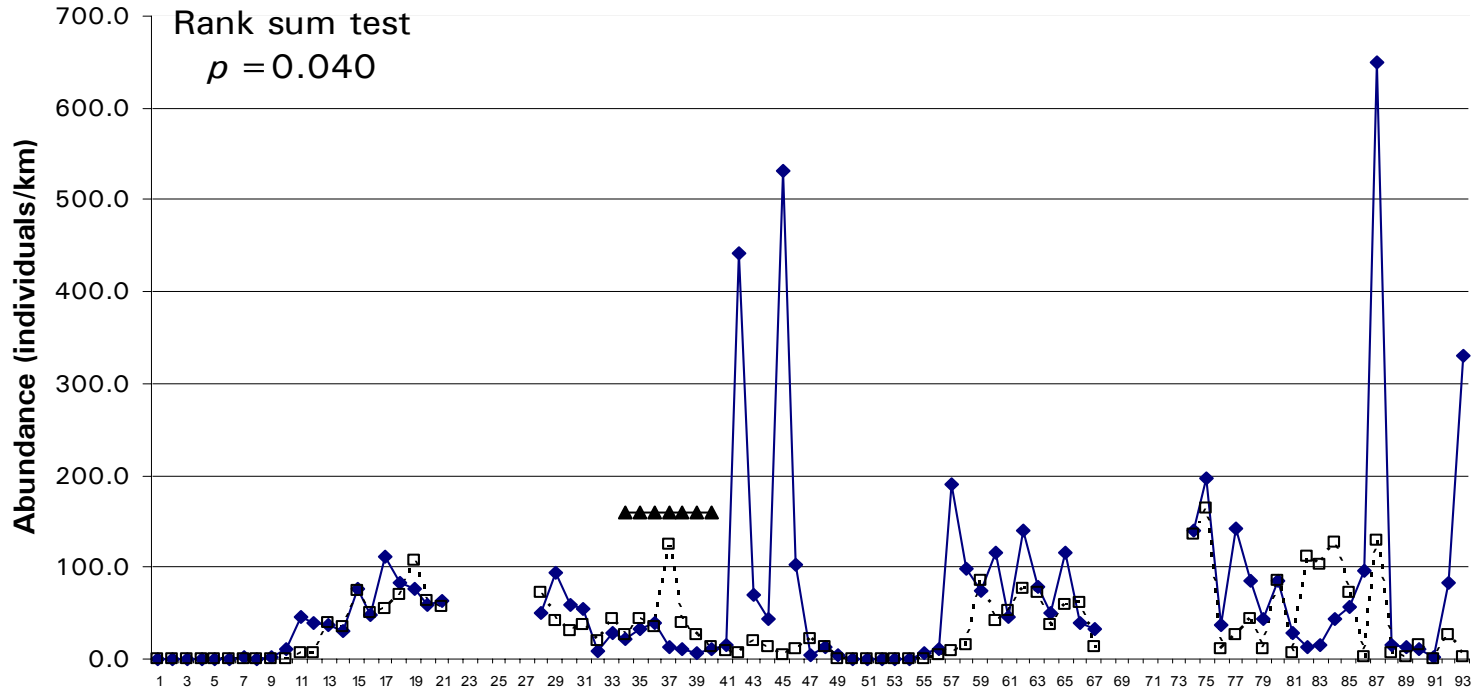
[a]Week 1 = 12/16/00

Weekly comparison of laughing gull abundance at transect 2 and control



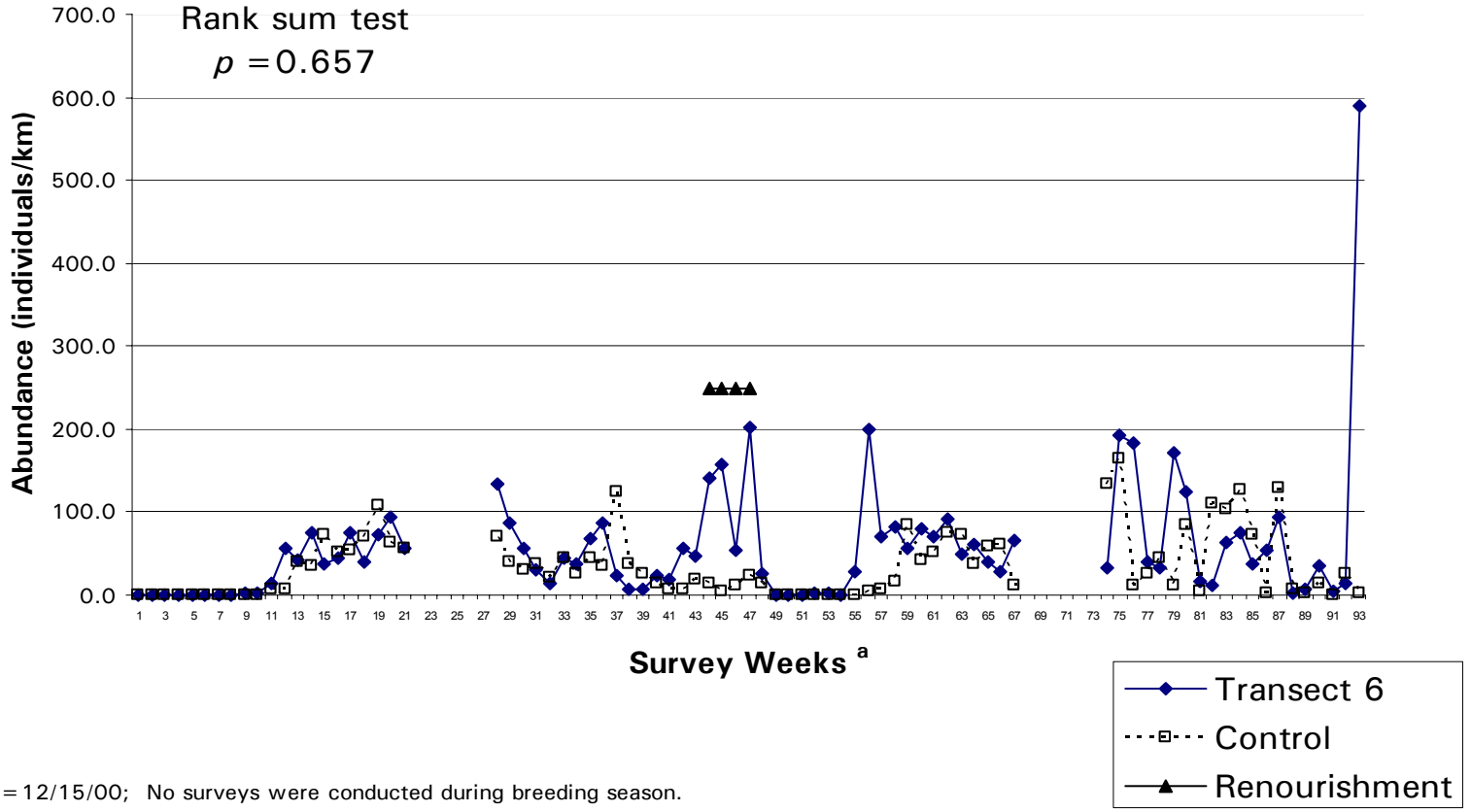
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of laughing gull abundance at transect 5 and control



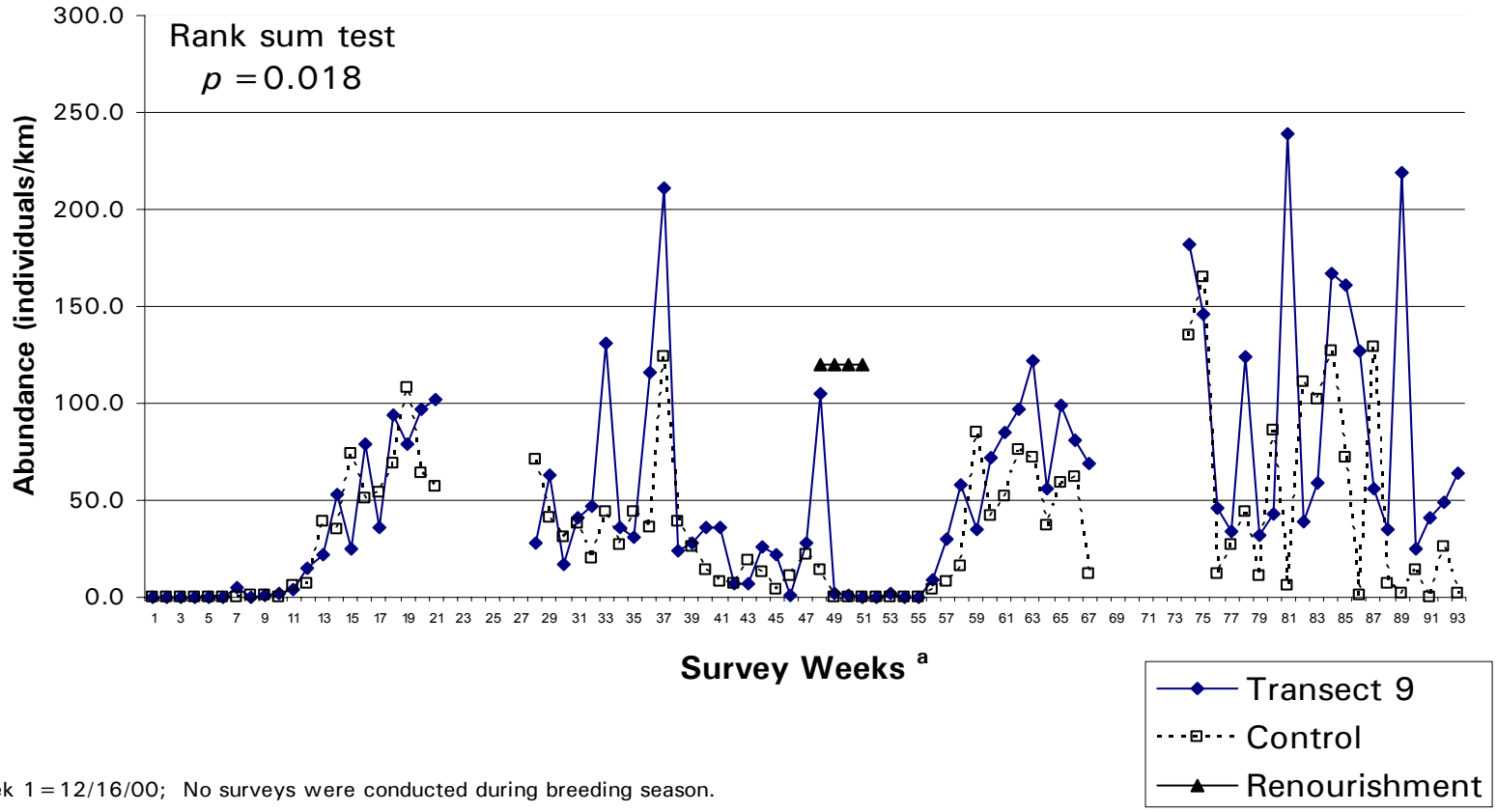
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of laughing gull abundance at transect 6 and control



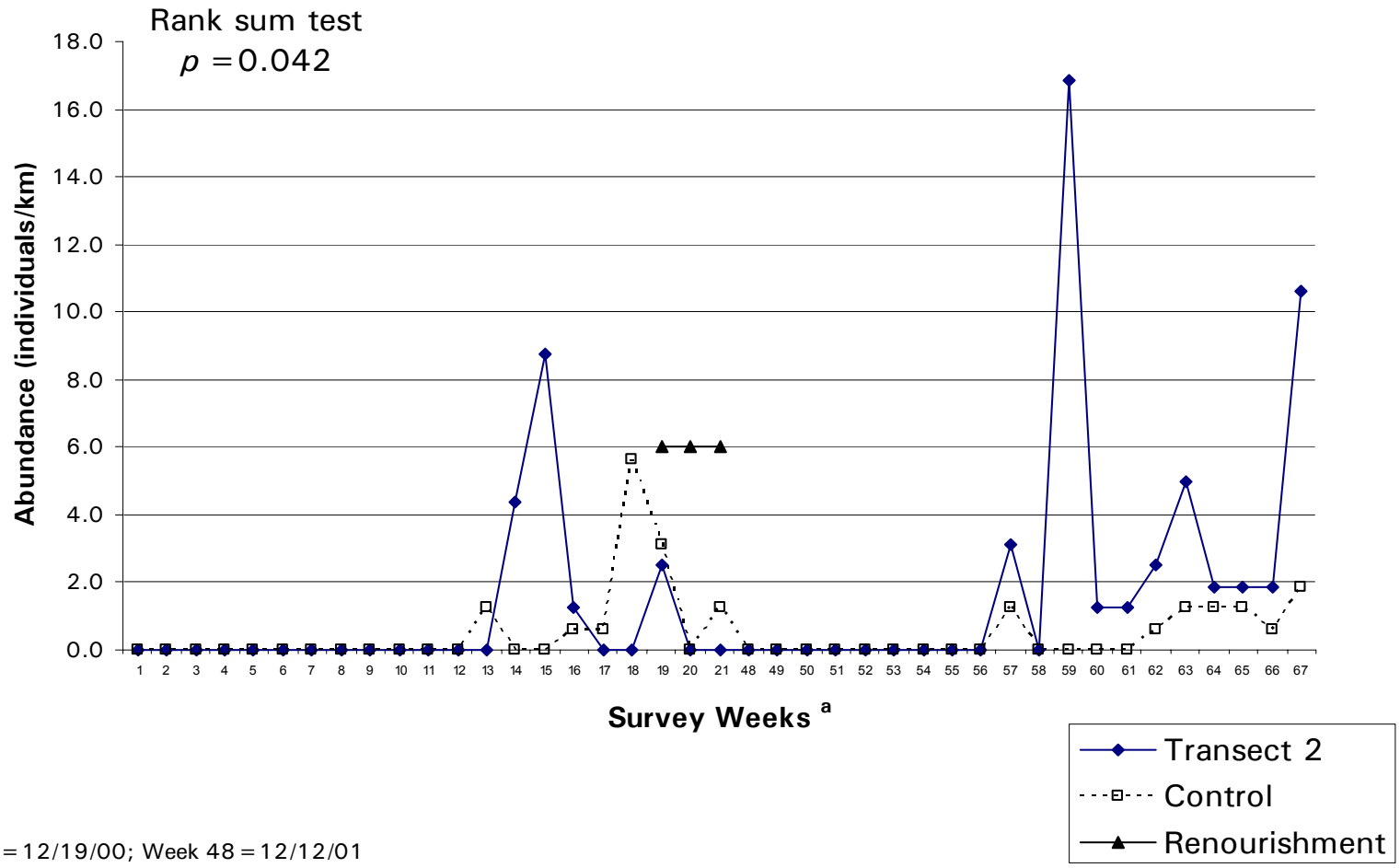
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of laughing gull abundance at transect 9 and control



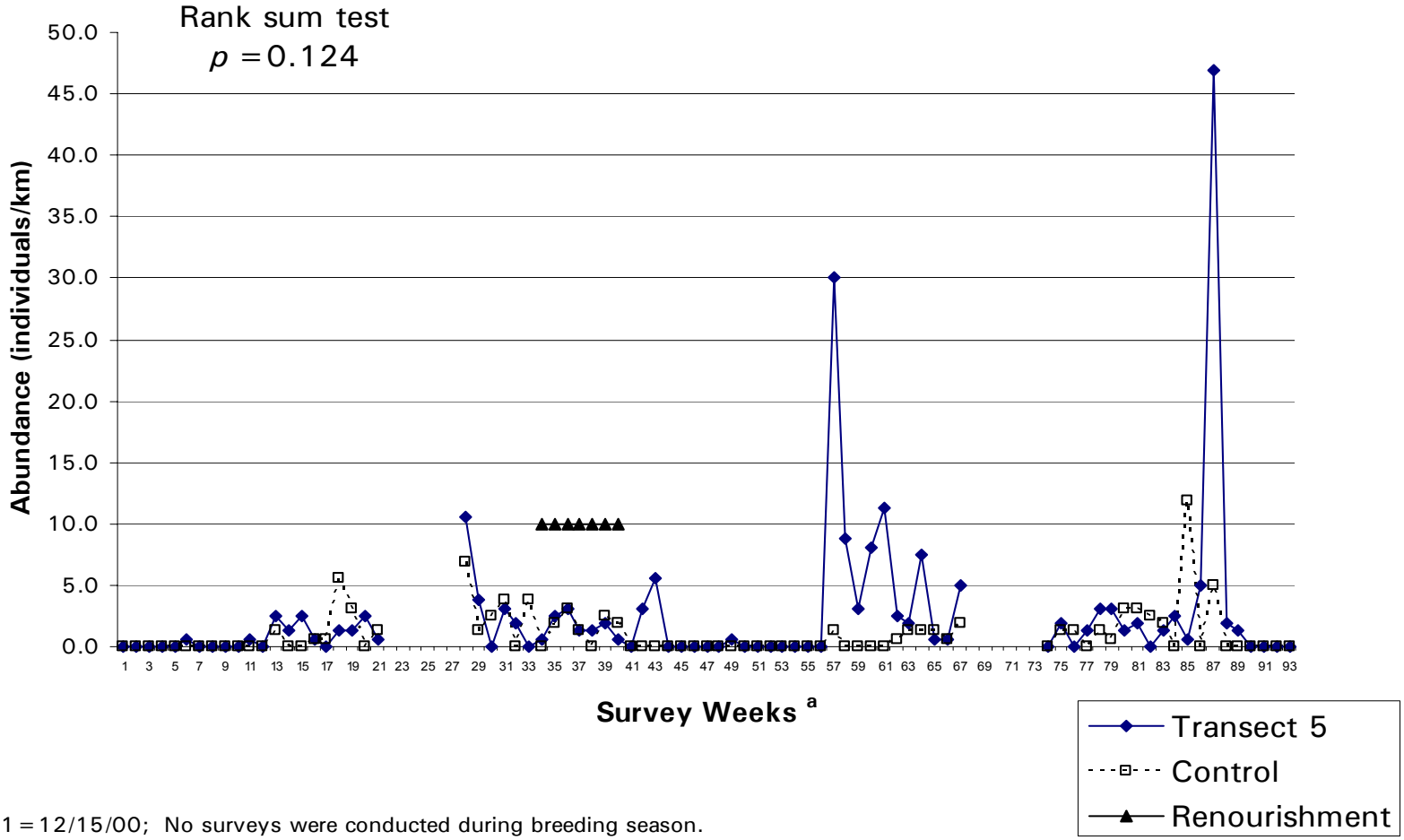
[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of royal tern abundance at transect 2 and control



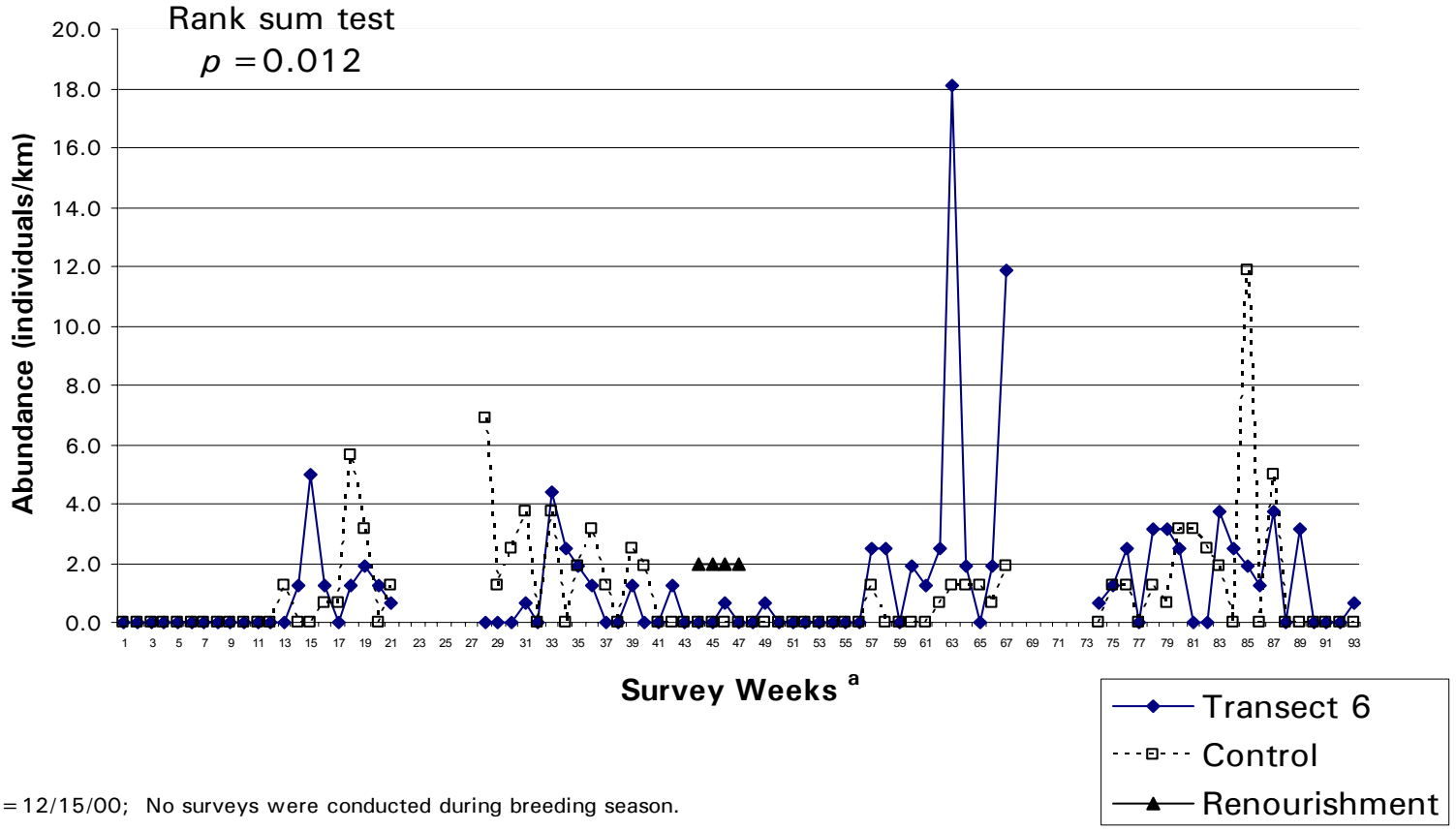
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of royal tern abundance at transect 5 and control



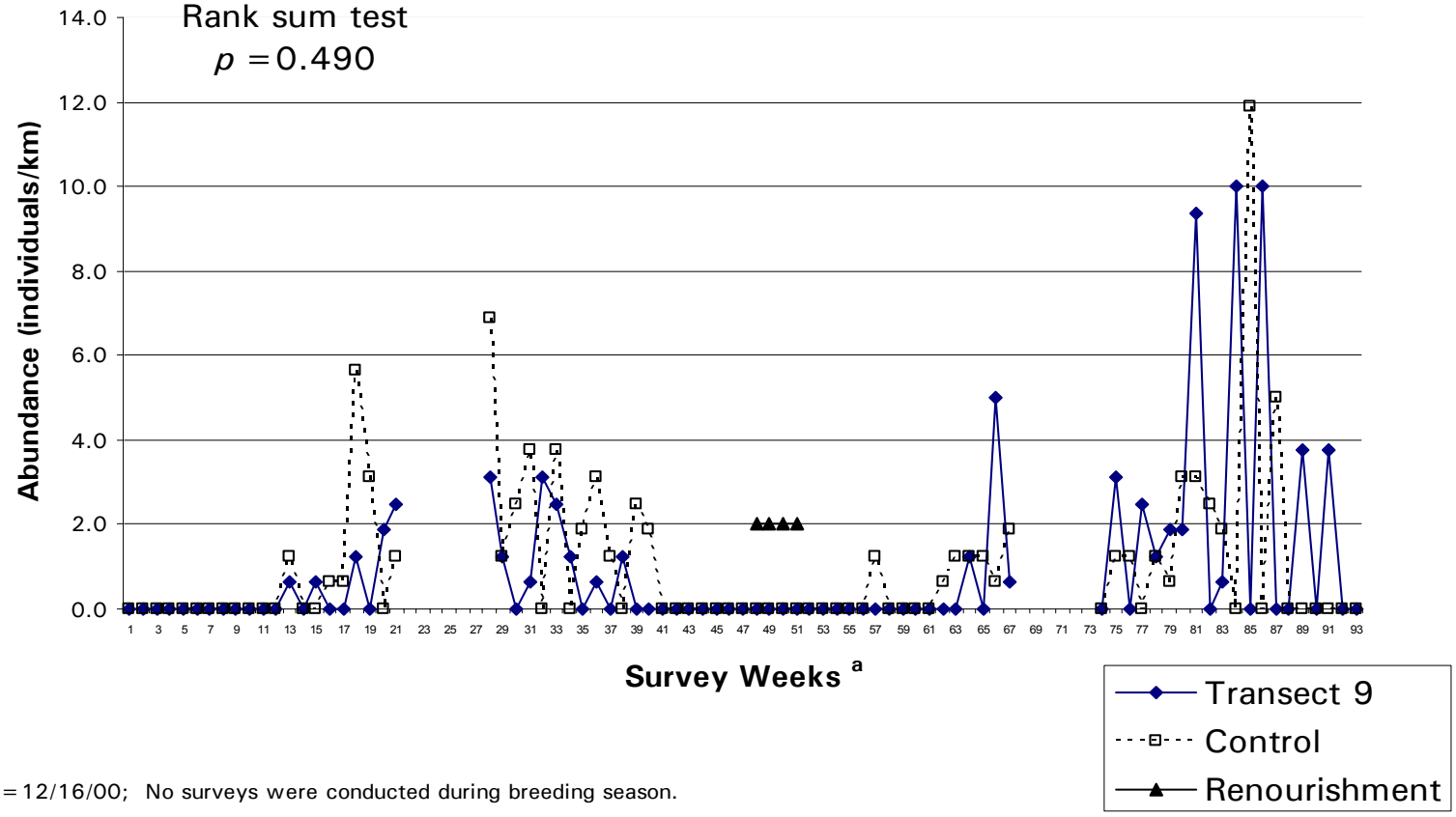
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of royal tern abundance at transect 6 and control



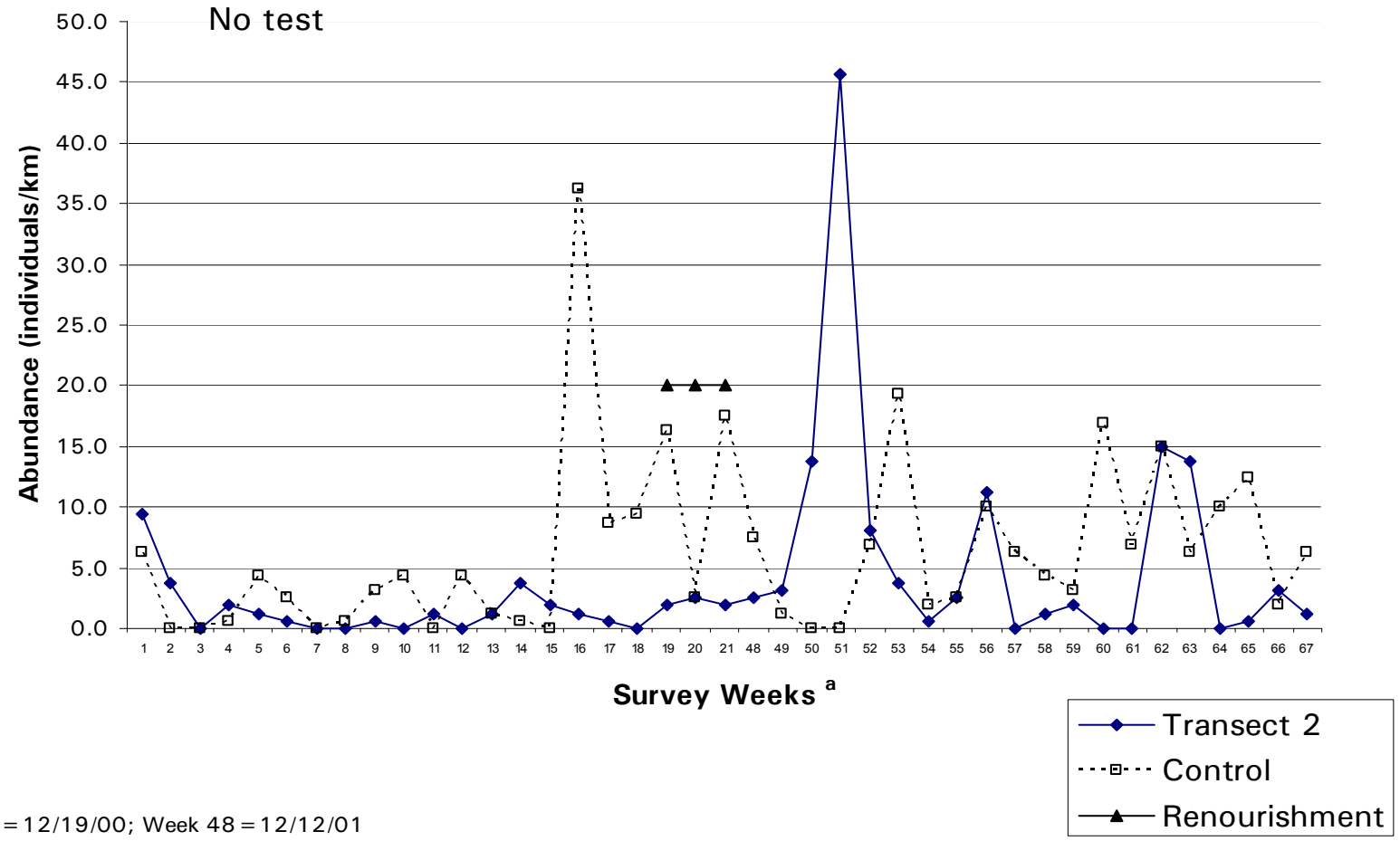
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of royal tern abundance at transect 9 and control



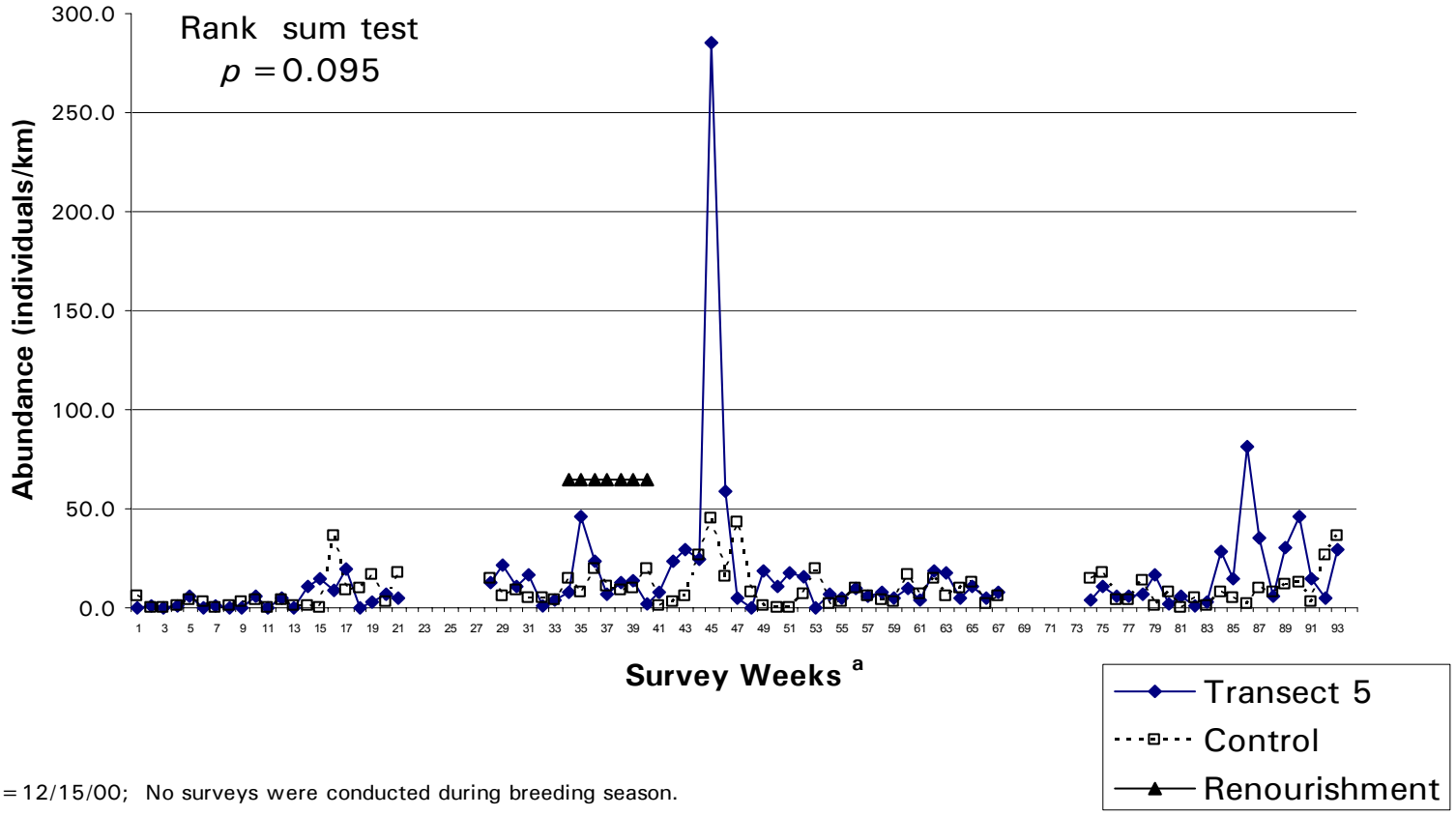
[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of brown pelican abundance at transect 2 and control



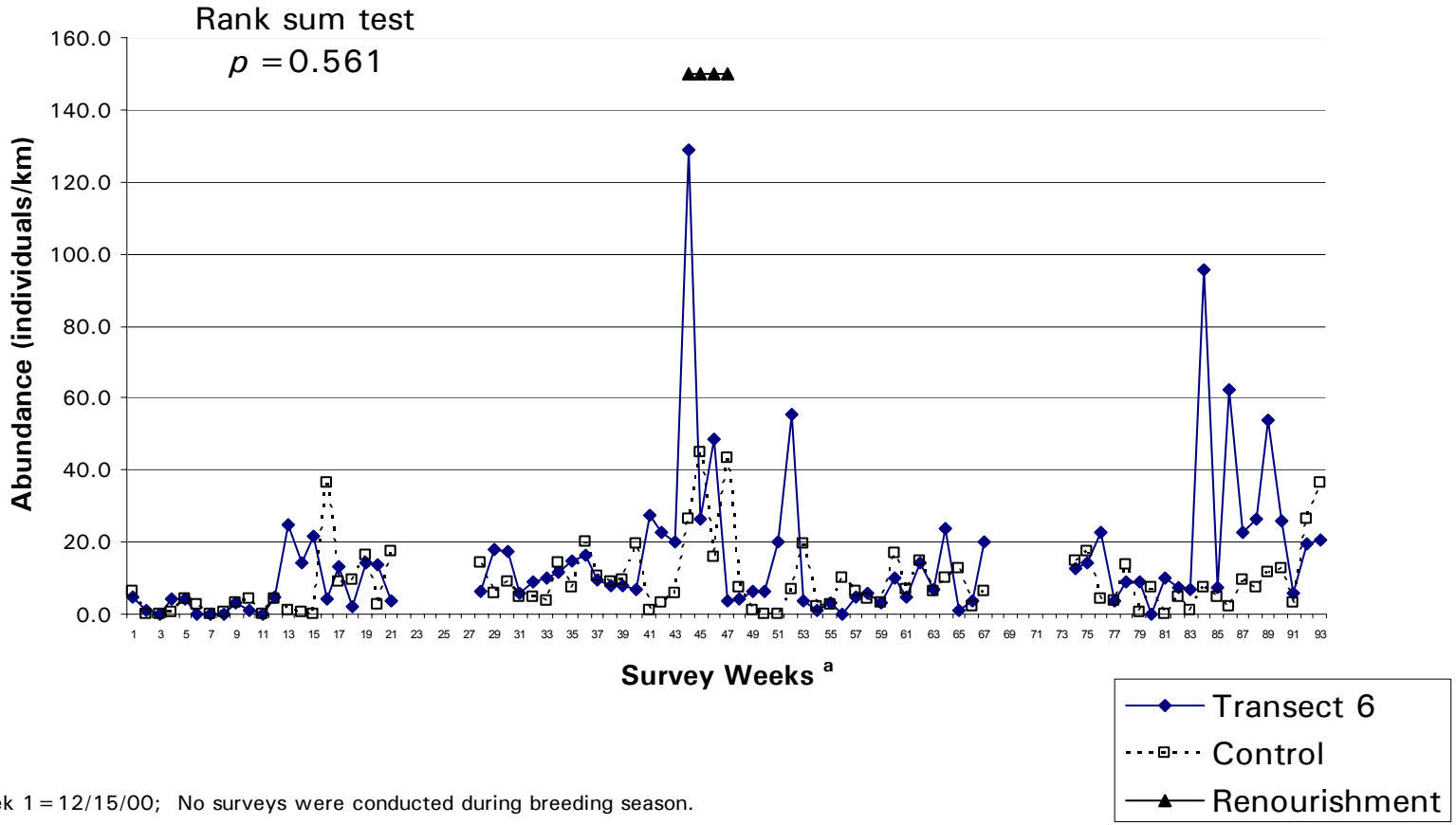
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of brown pelican abundance at transect 5 and control



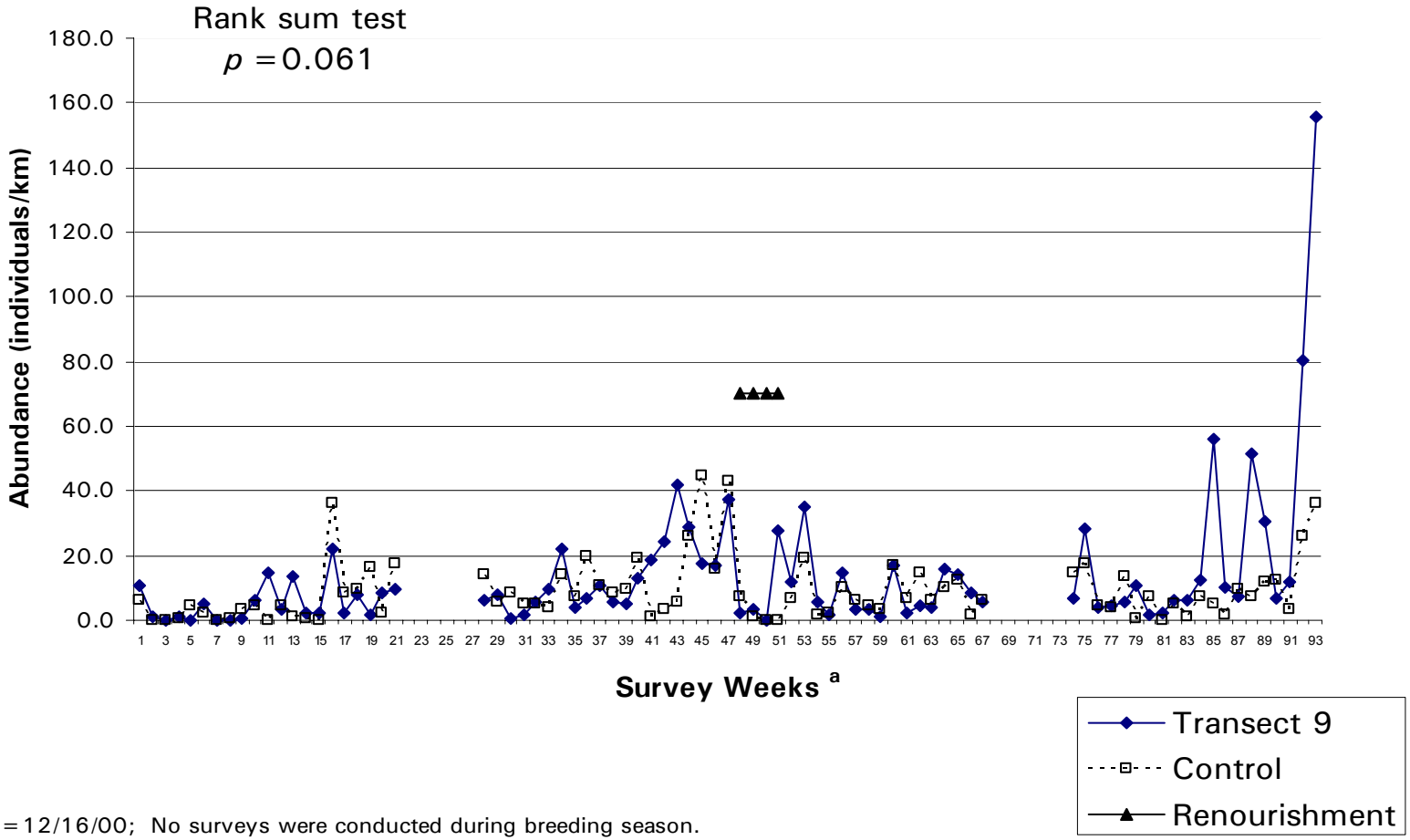
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of brown pelican abundance at transect 6 and control



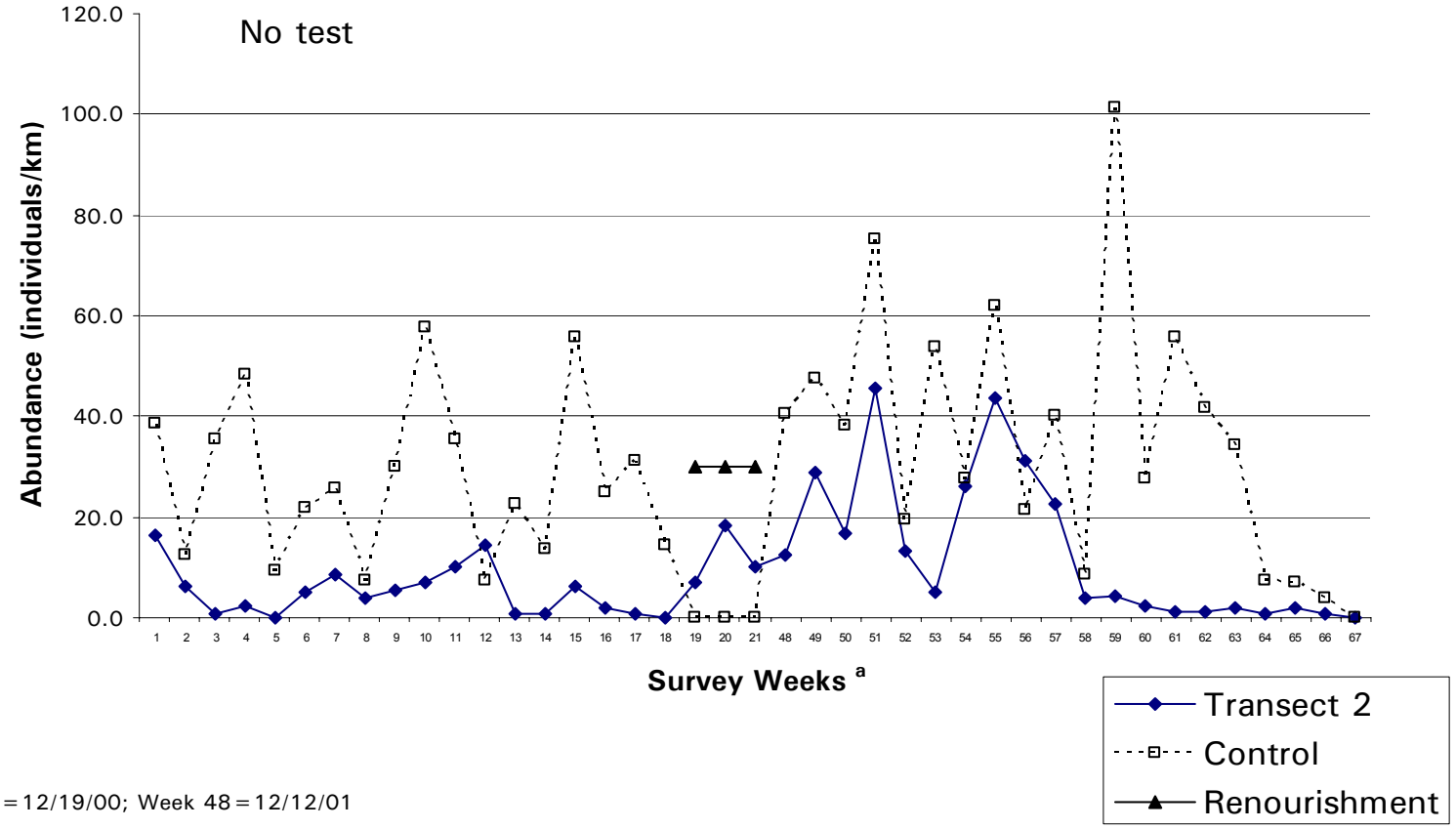
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of brown pelican abundance at transect 9 and control



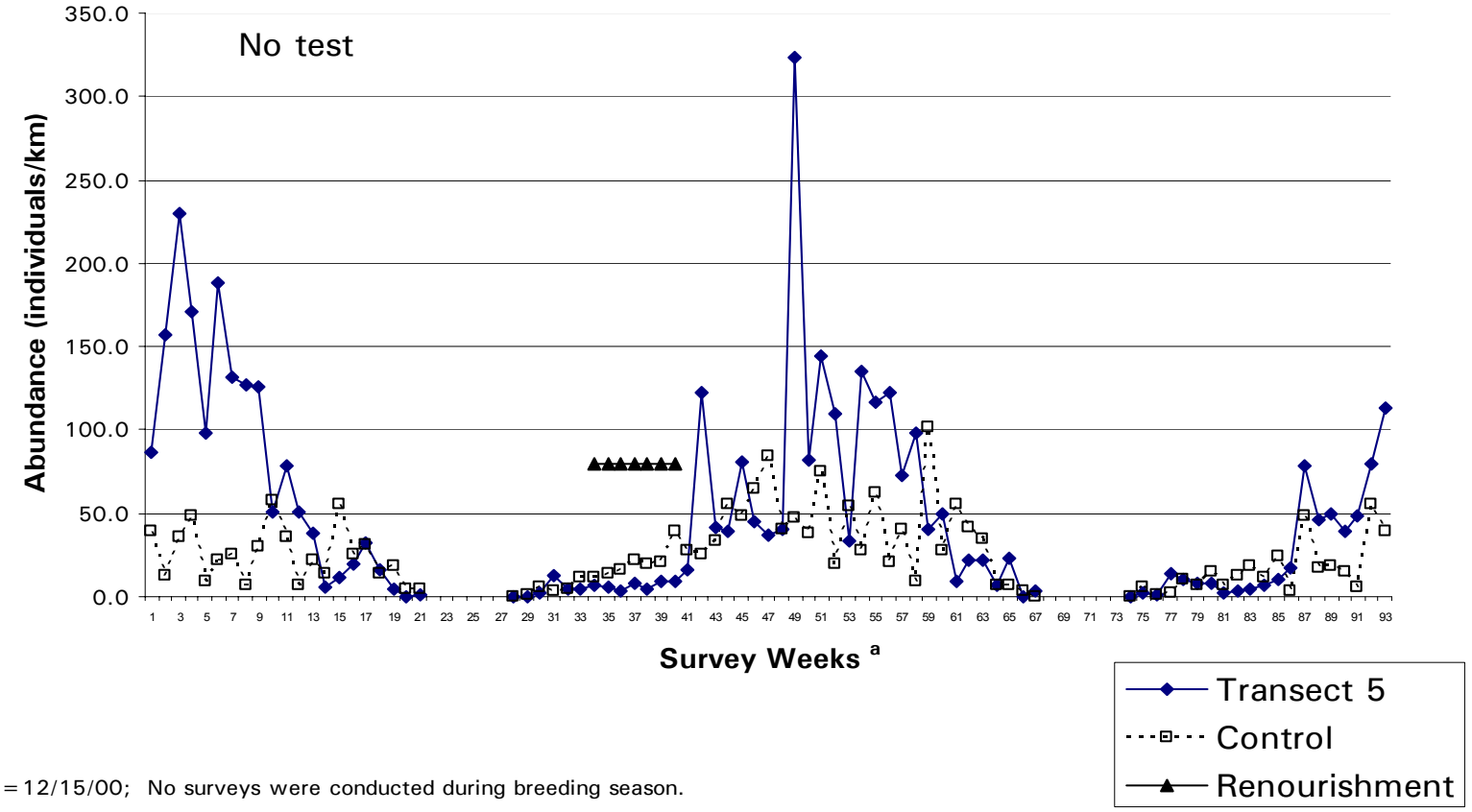
[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of ring-billed gull abundance at transect 2 and control



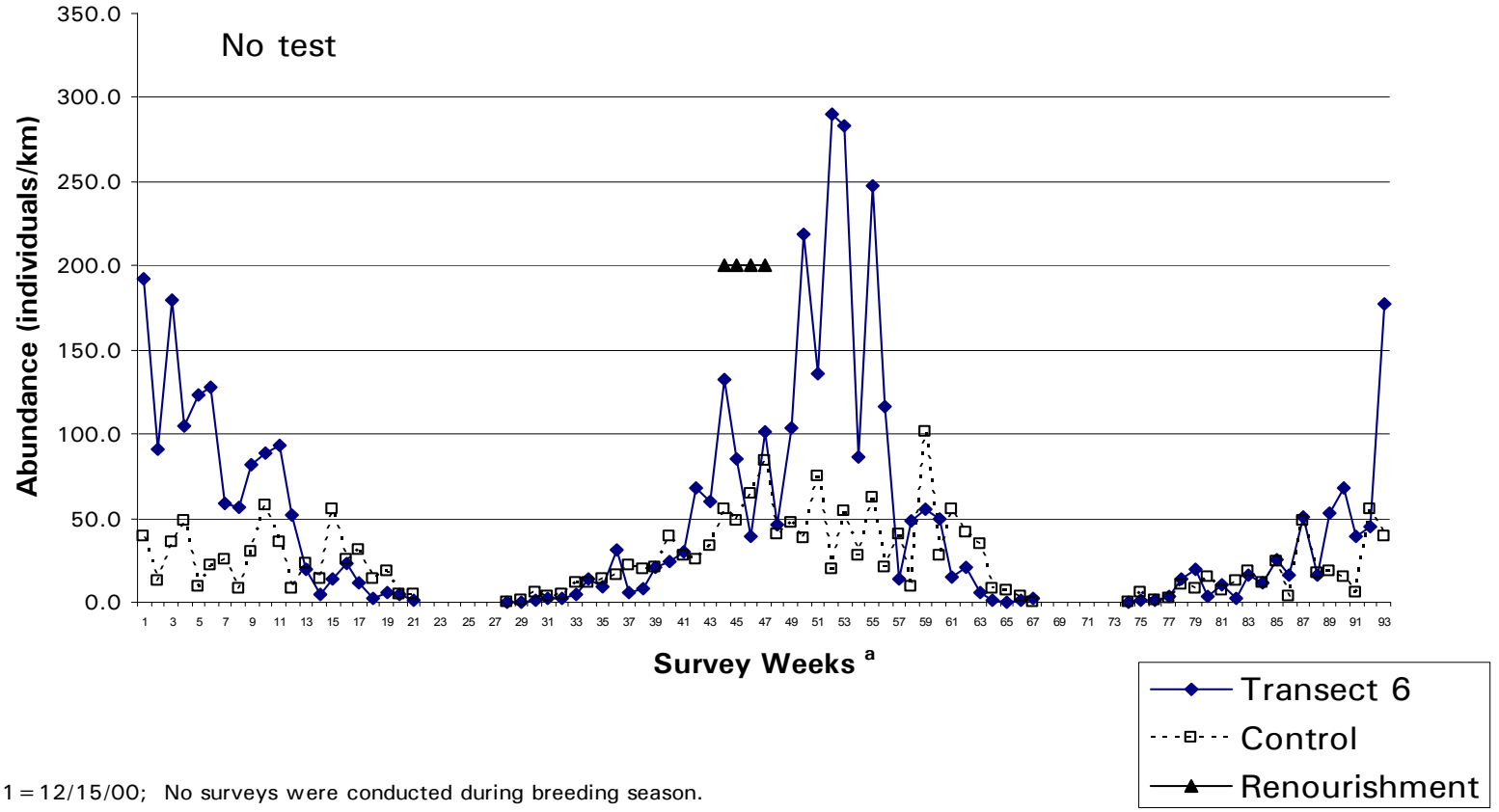
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of ring-billed gull abundance at transect 5 and control



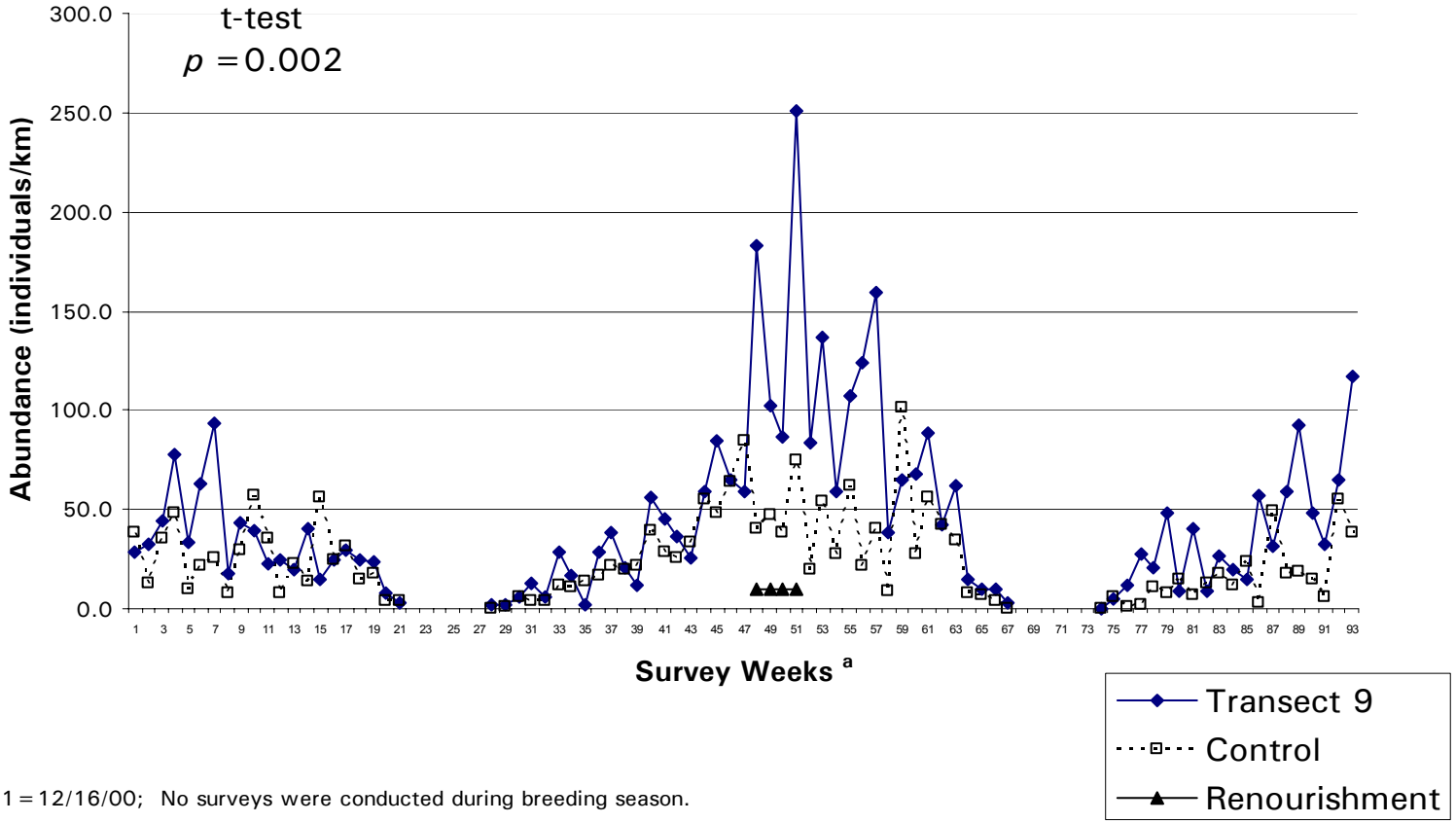
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of ring-billed gull abundance at transect 6 and control



[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of ring-billed gull abundance at transect 9 and control

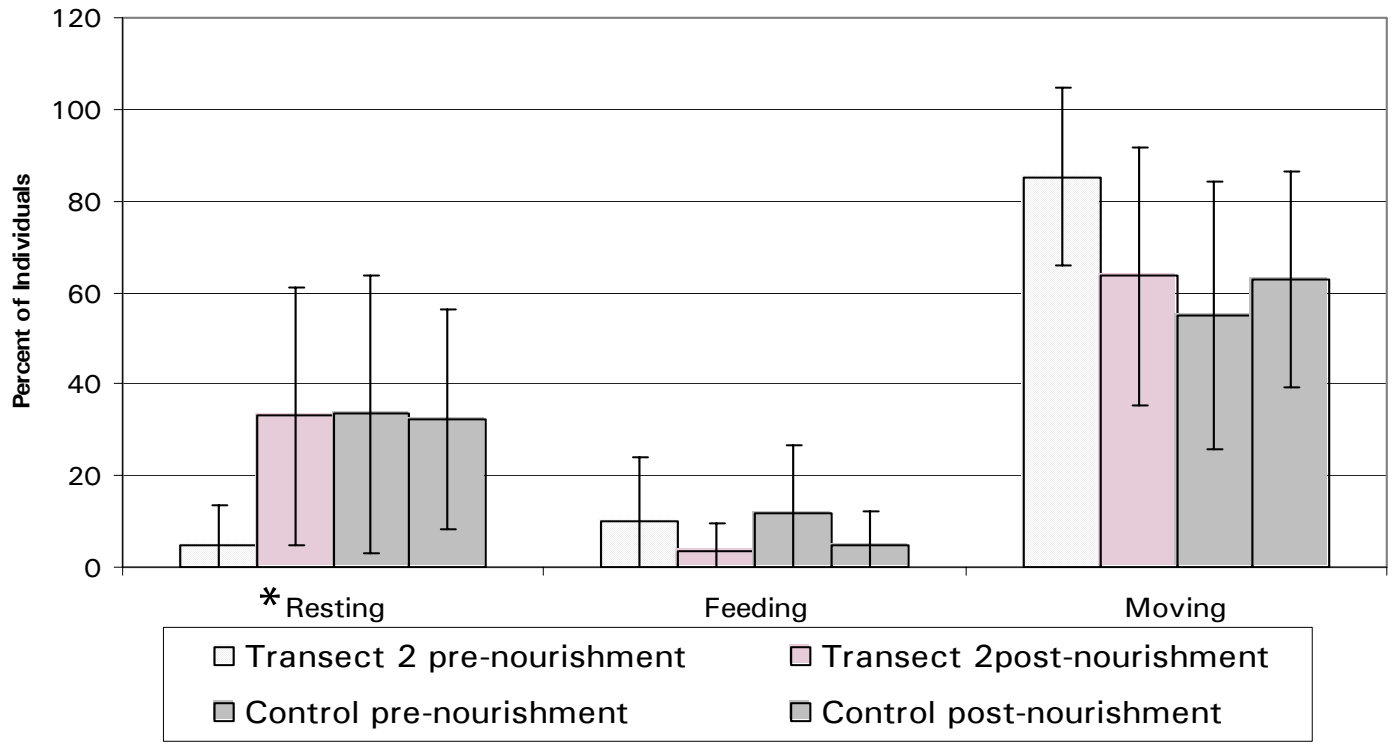


[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

APPENDIX L

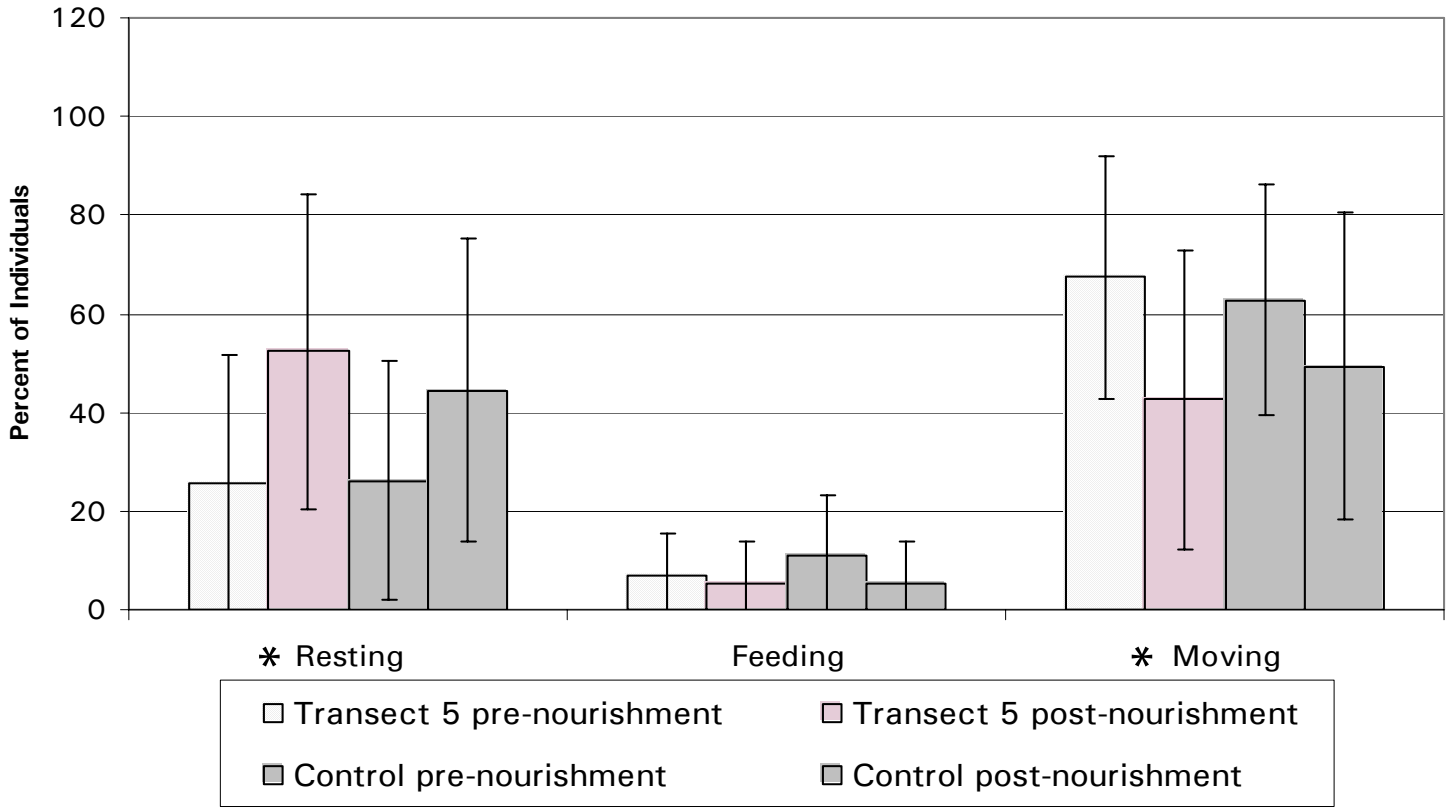
ACTIVITY OF SELECTED WATERBIRDS AND SHOREBIRDS

Laughing gull activity at Transect 2 before and after beach renourishment



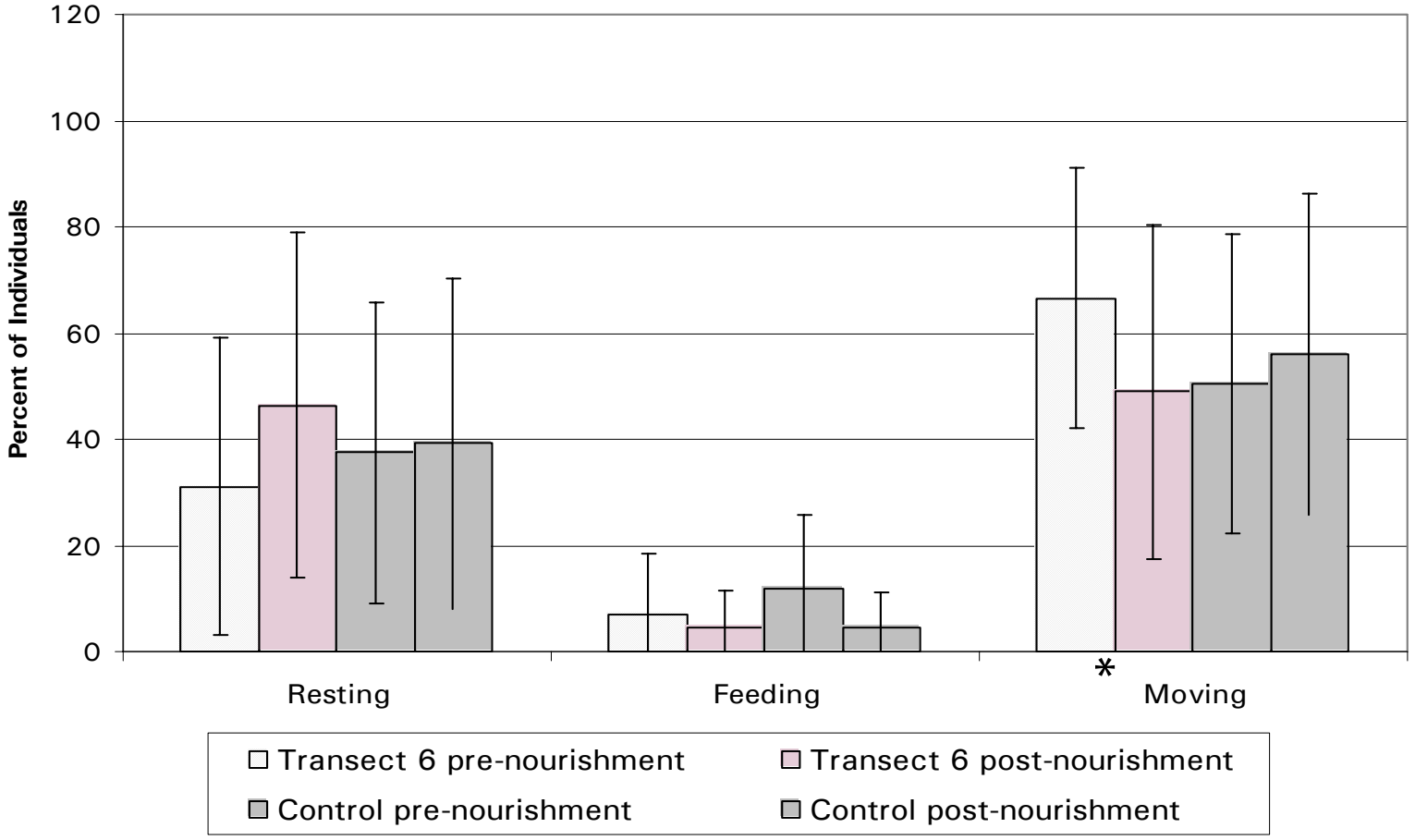
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Laughing gull activity at Transect 5 before and after beach renourishment



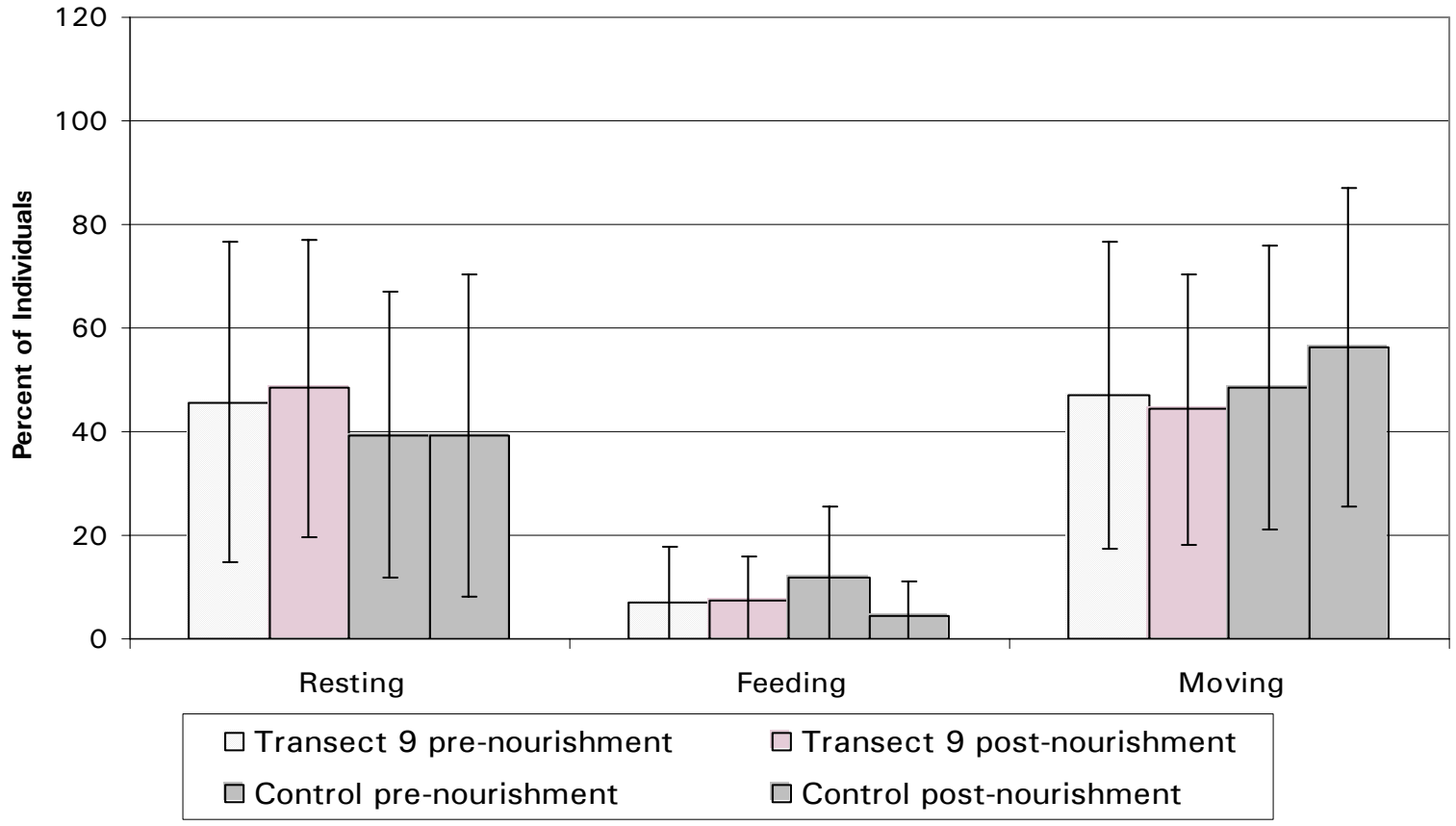
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Laughing gull activity at Transect 6 before and after beach renourishment



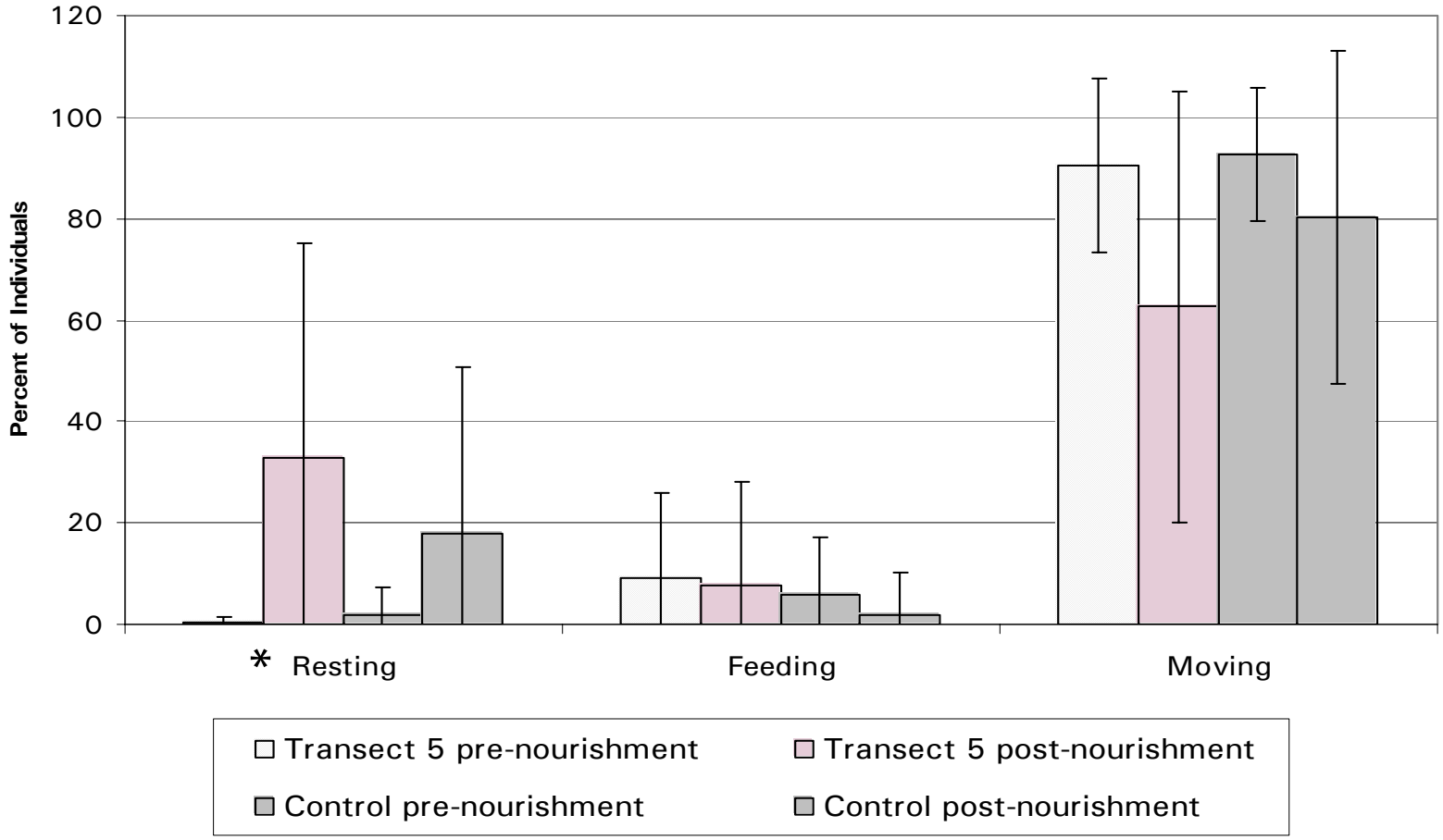
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Laughing gull activity at Transect 9 before and after beach renourishment



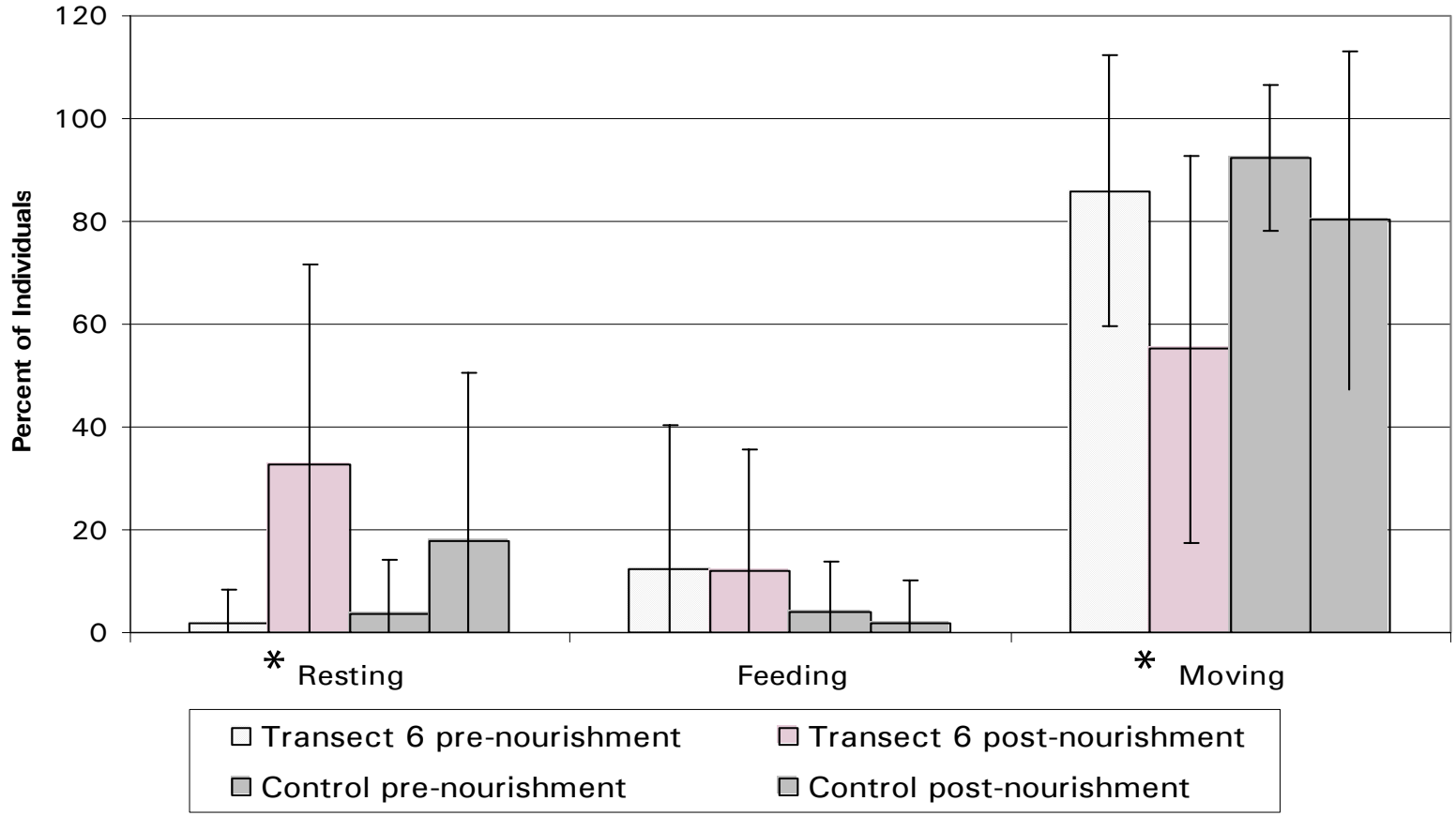
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Royal tern activity at Transect 5 before and after beach renourishment



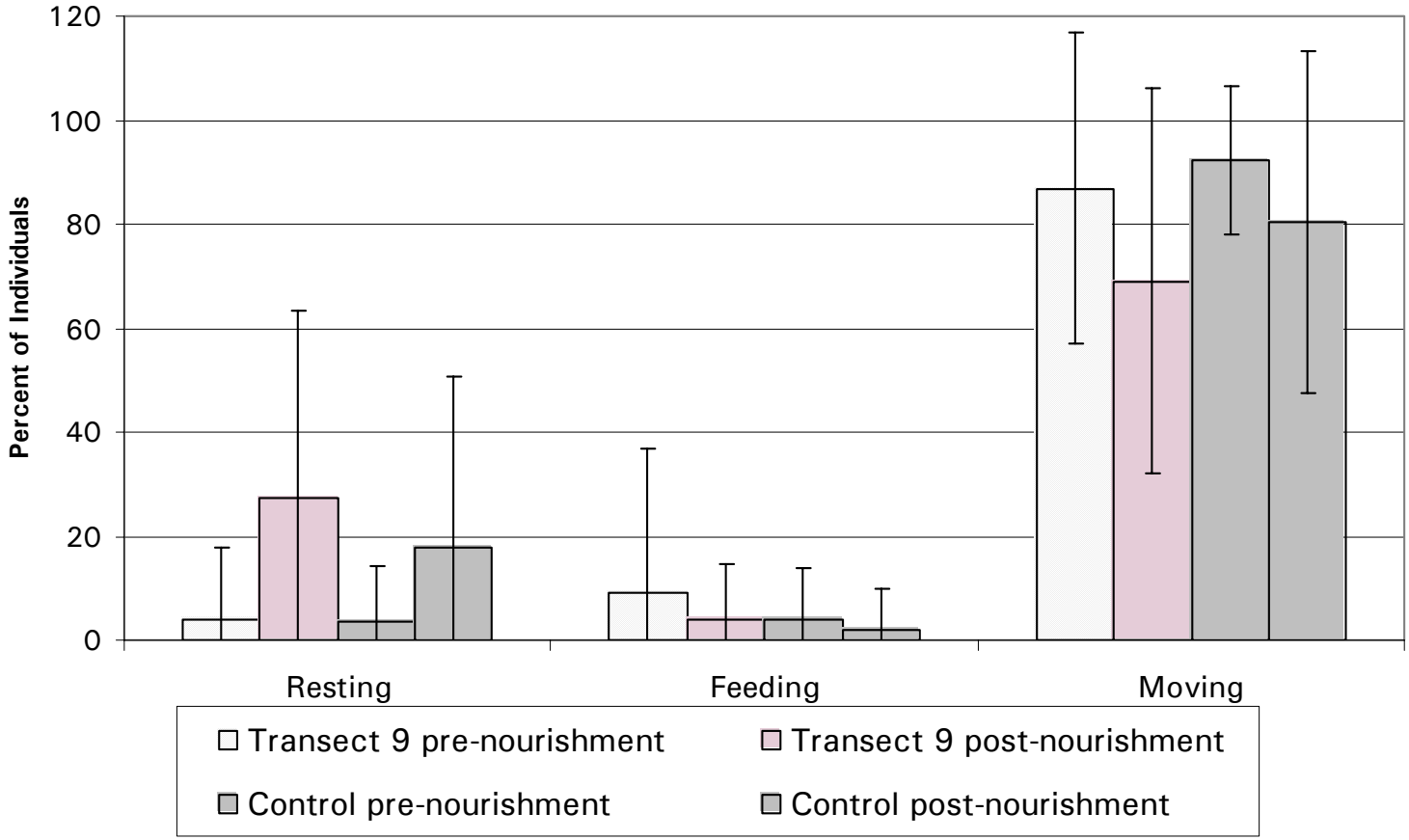
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Royal tern activity at Transect 6 before and after beach renourishment



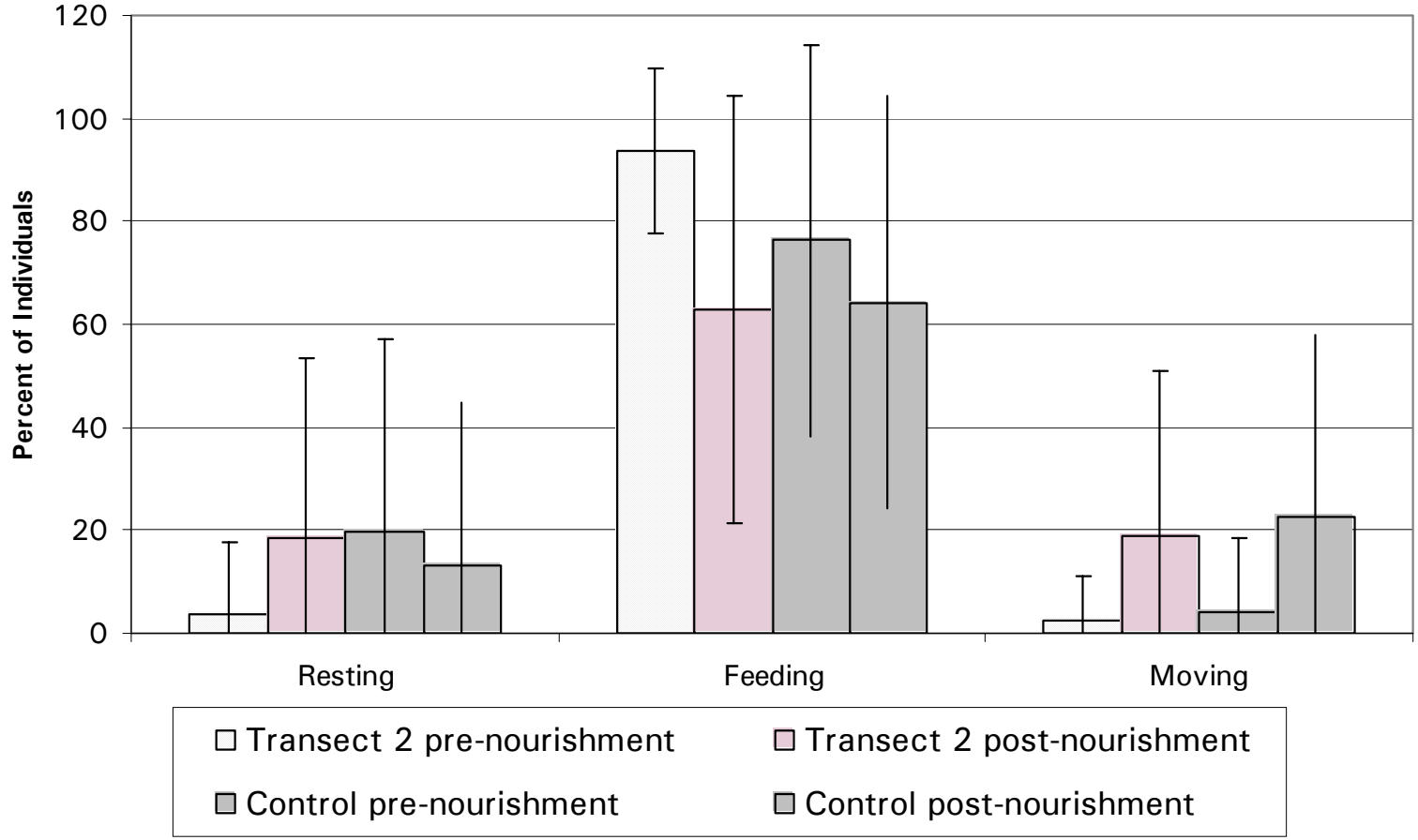
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Royal tern activity at Transect 9 before and after beach renourishment



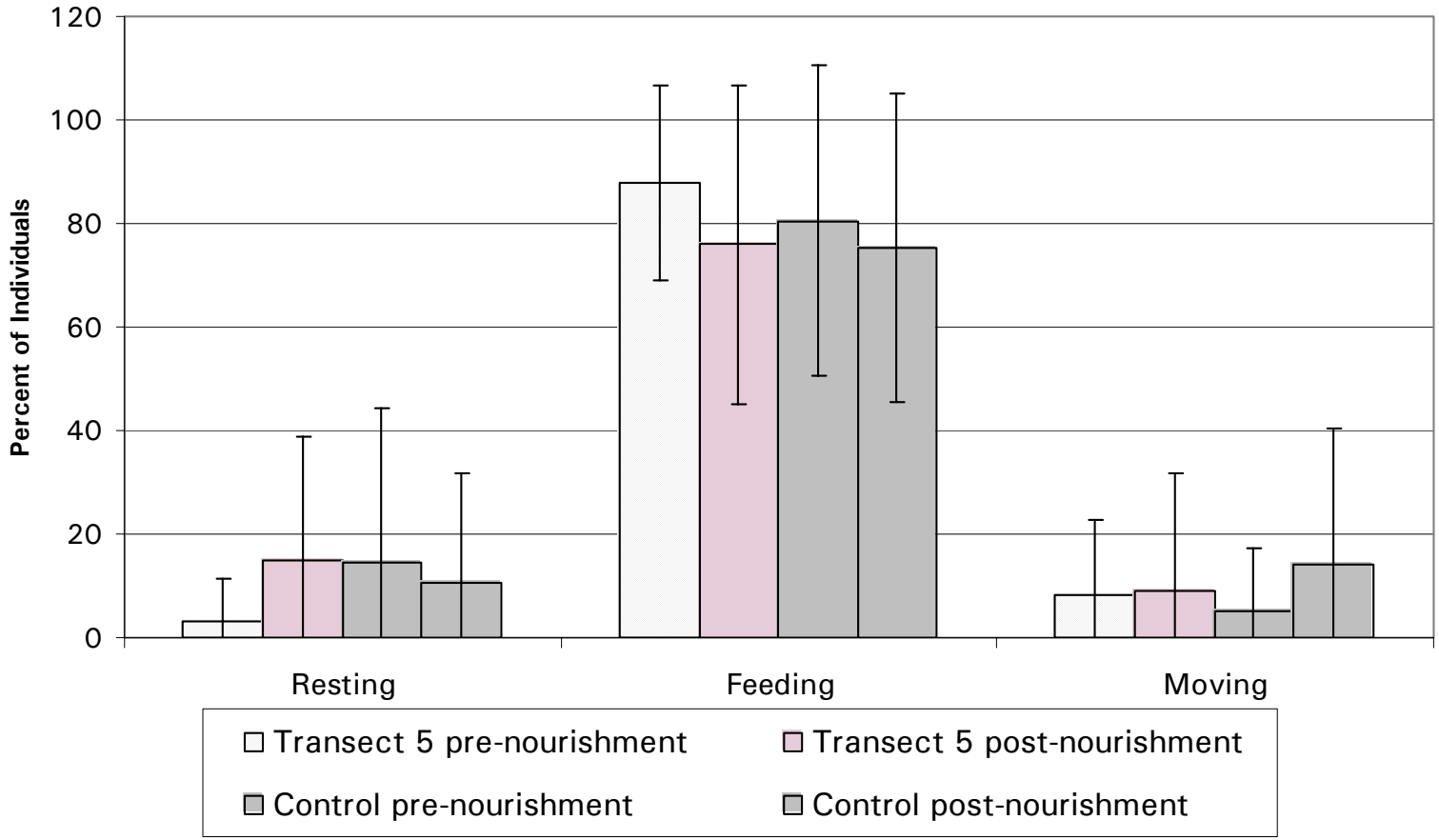
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Willet activity at Transect 2 before and after beach renourishment



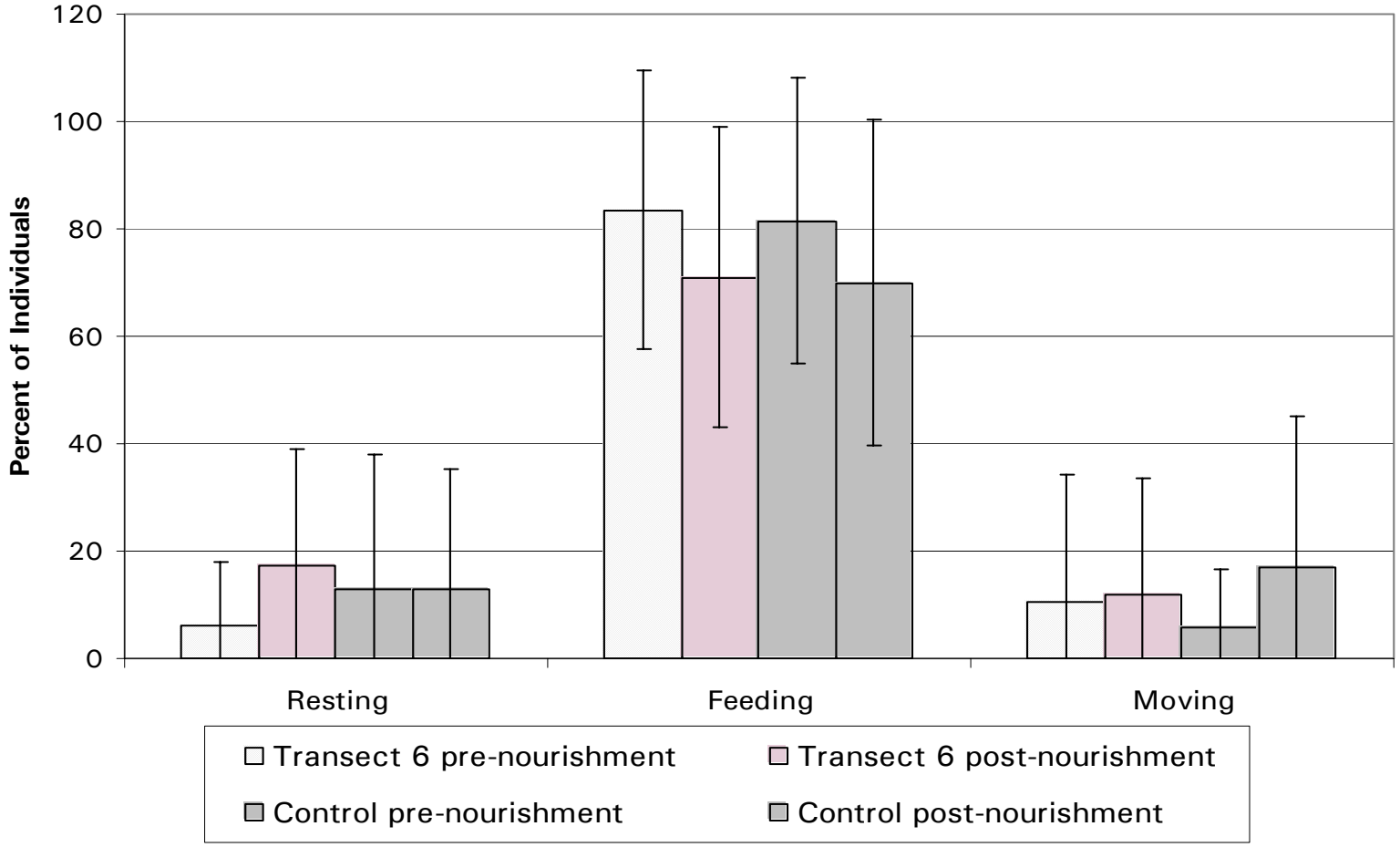
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Willet activity at Transect 5 before and after beach renourishment



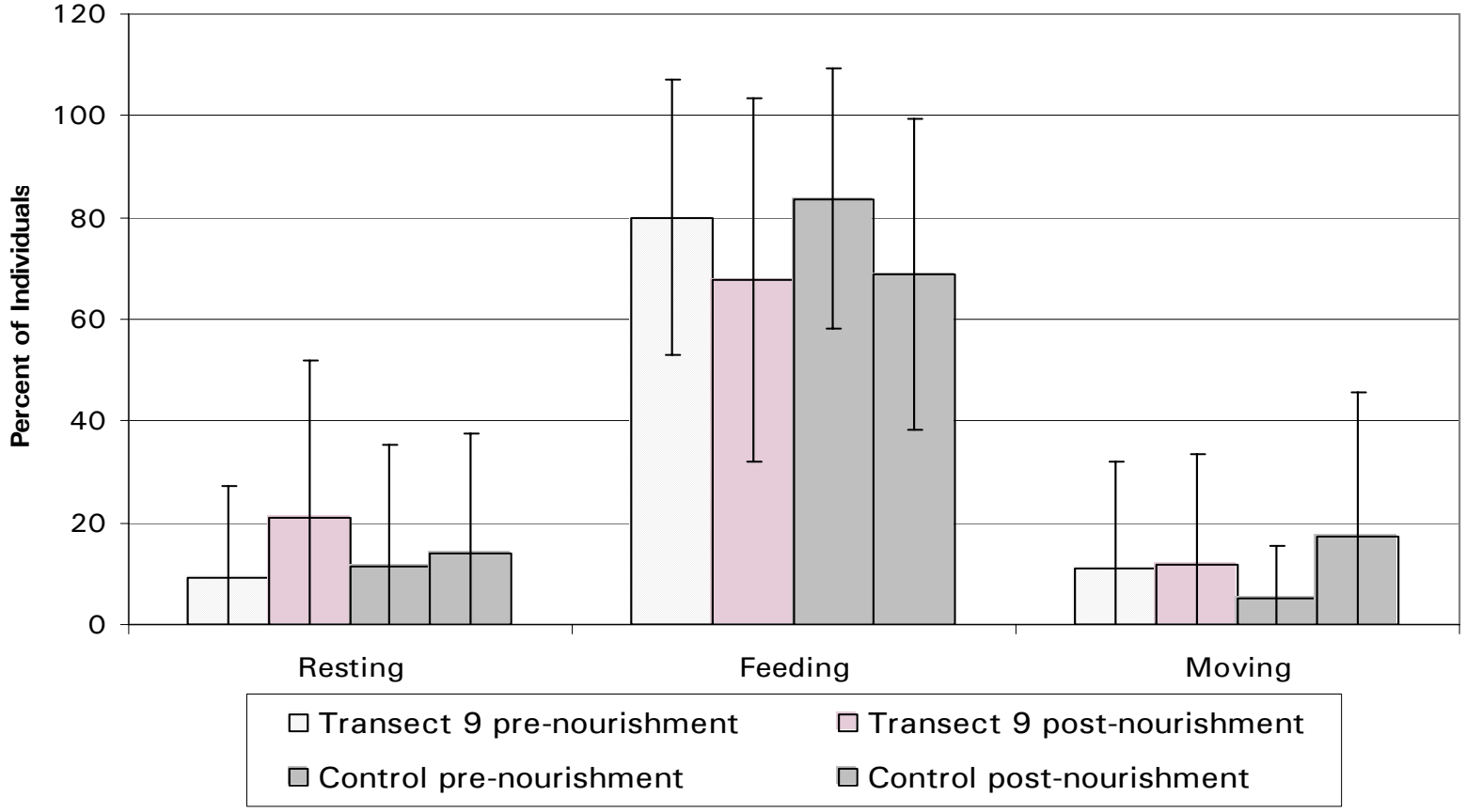
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Willet activity at Transect 6 before and after beach renourishment



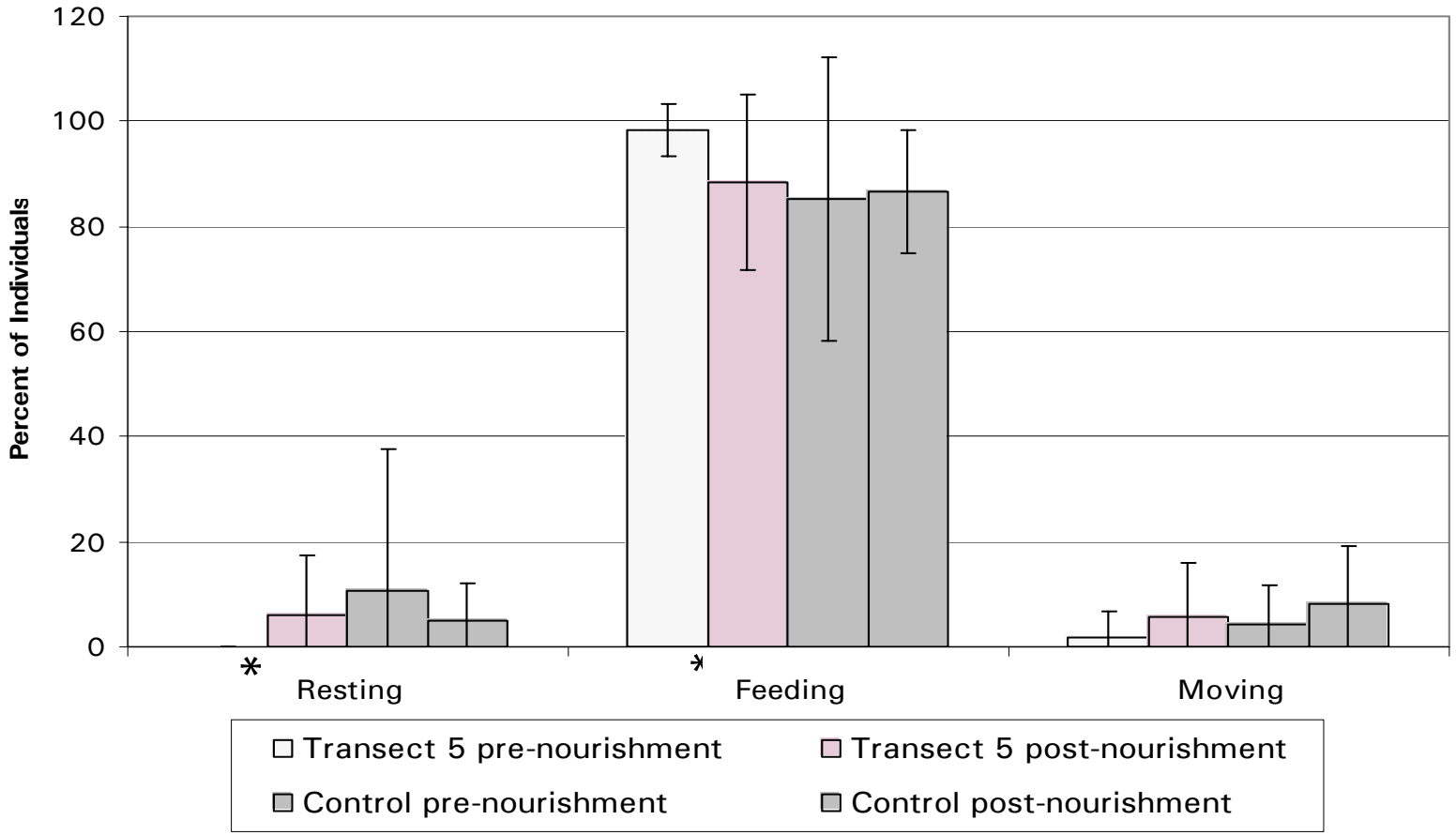
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Willet activity at Transect 9 before and after beach renourishment



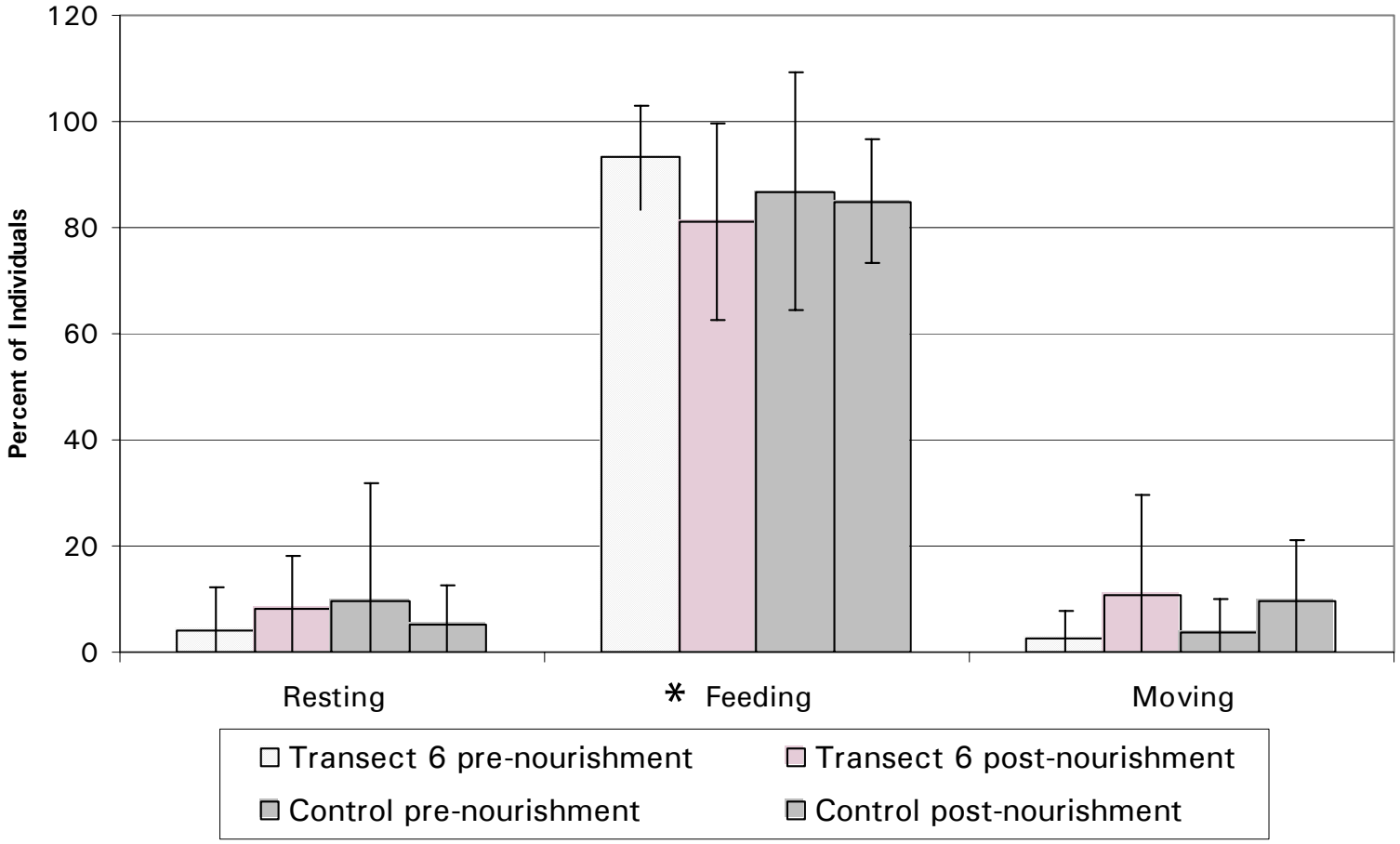
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Sanderling activity at Transect 5 before and after beach renourishment



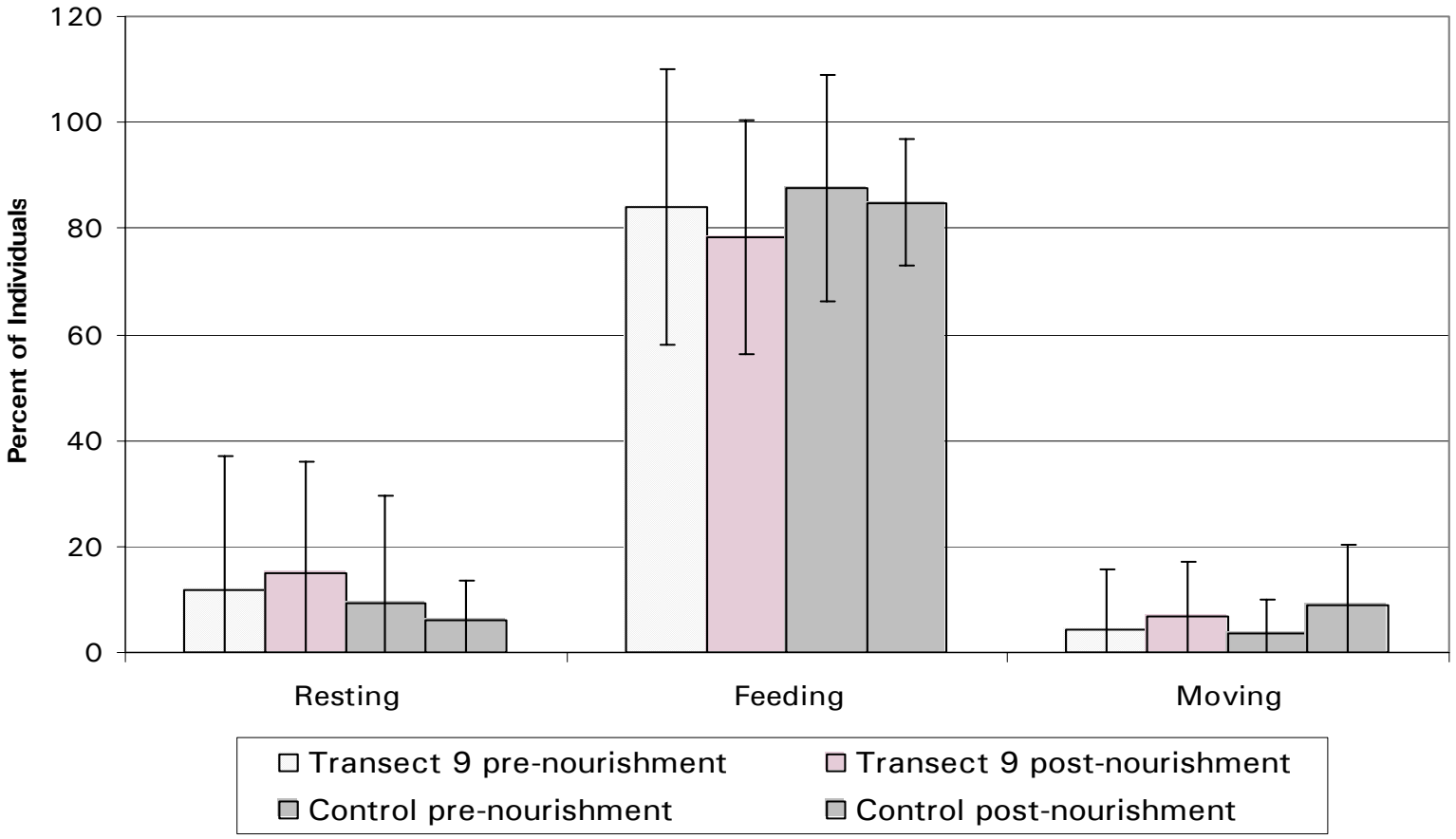
* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Sanderling activity at Transect 6 before and after beach renourishment



* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

Sanderling activity at Transect 9 before and after beach renourishment

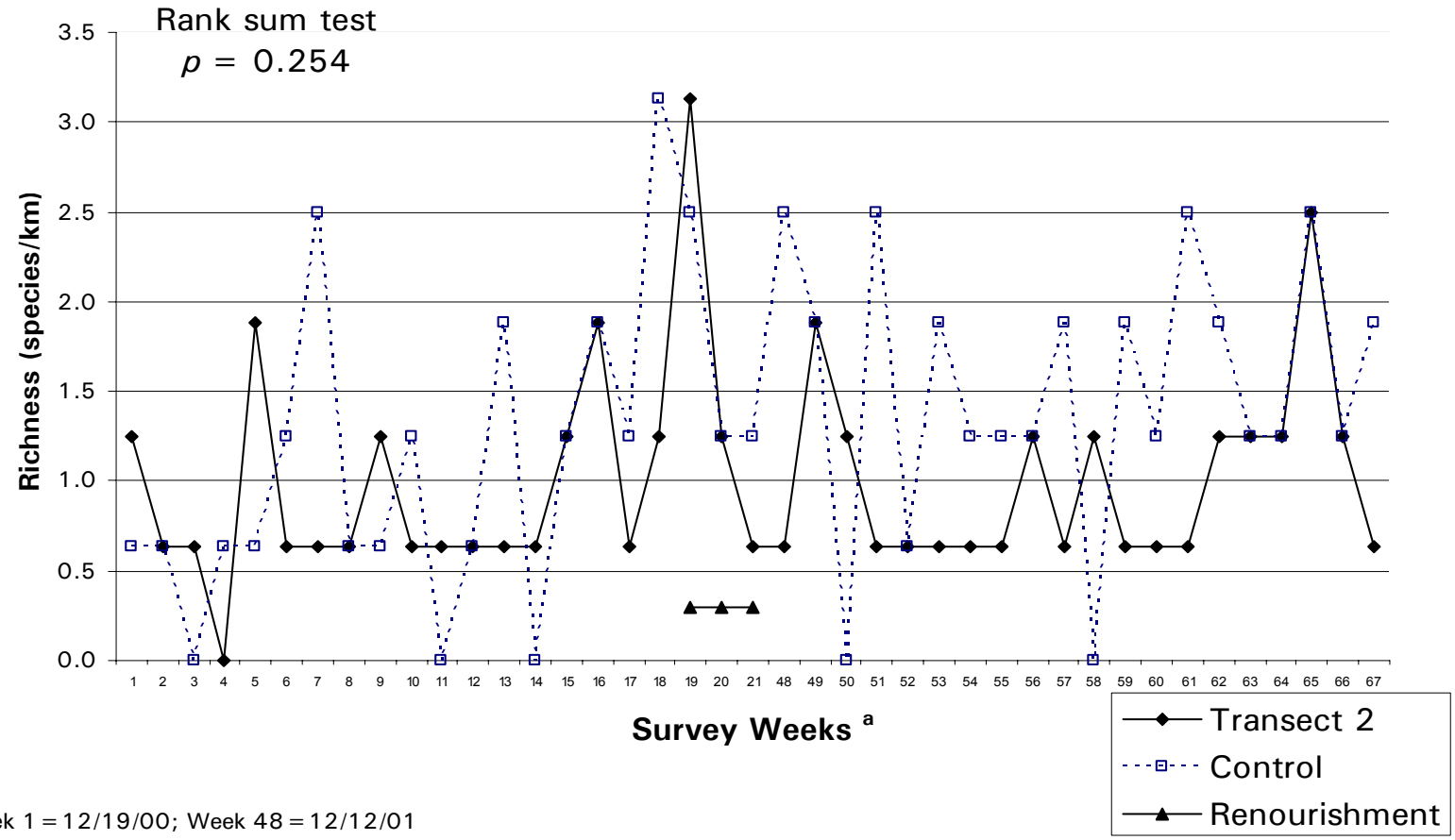


* Denotes significant difference at the renourished transect between the pre - and post - renourishment period.

APPENDIX M

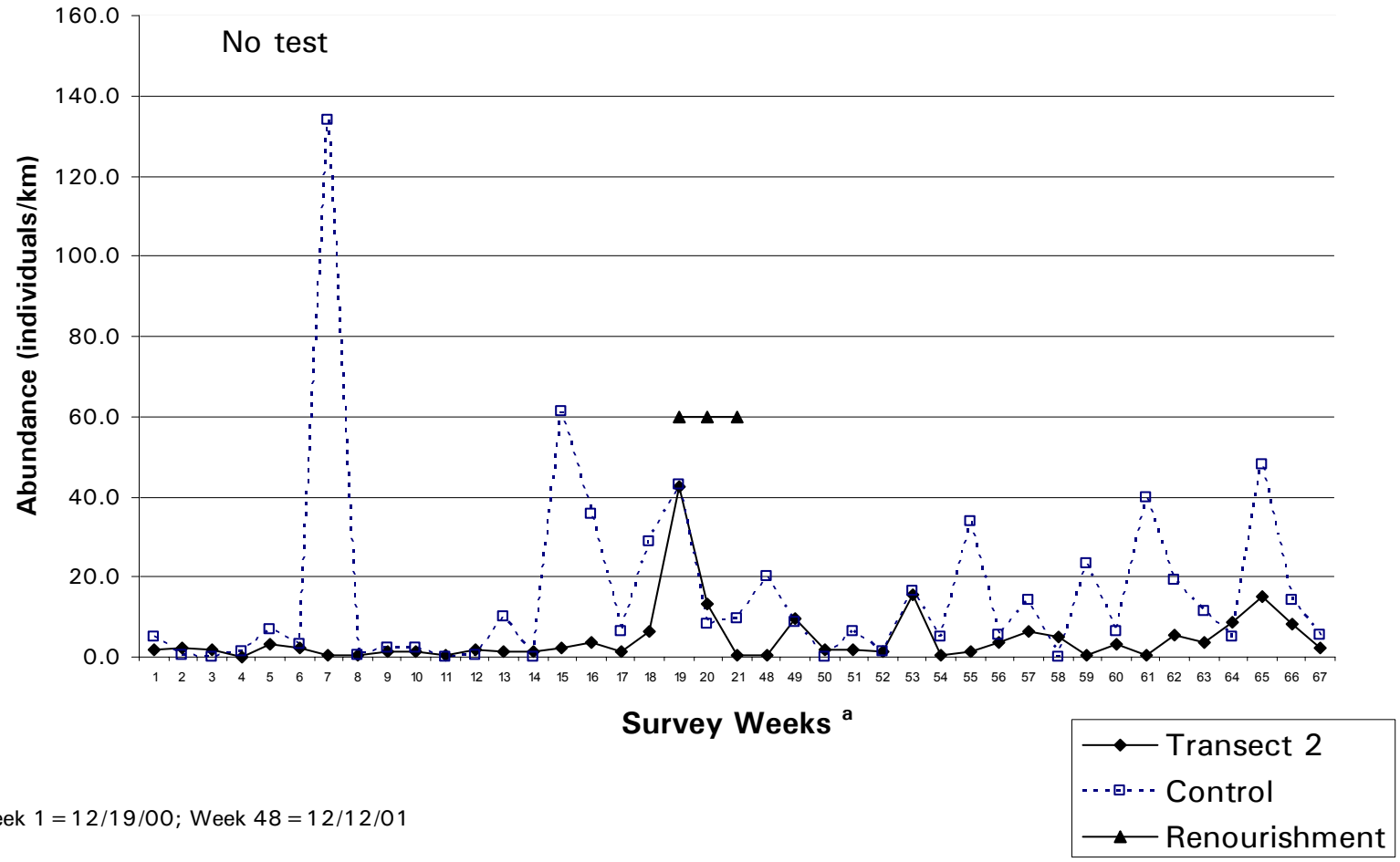
FIGURES DEPICTING WEEKLY SHOREBIRD RICHNESS AND ABUNDANCE AT RENOURISHED TRANSECTS AND CONTROL AREAS

Weekly comparison of shorebird richness at transect 2 and control



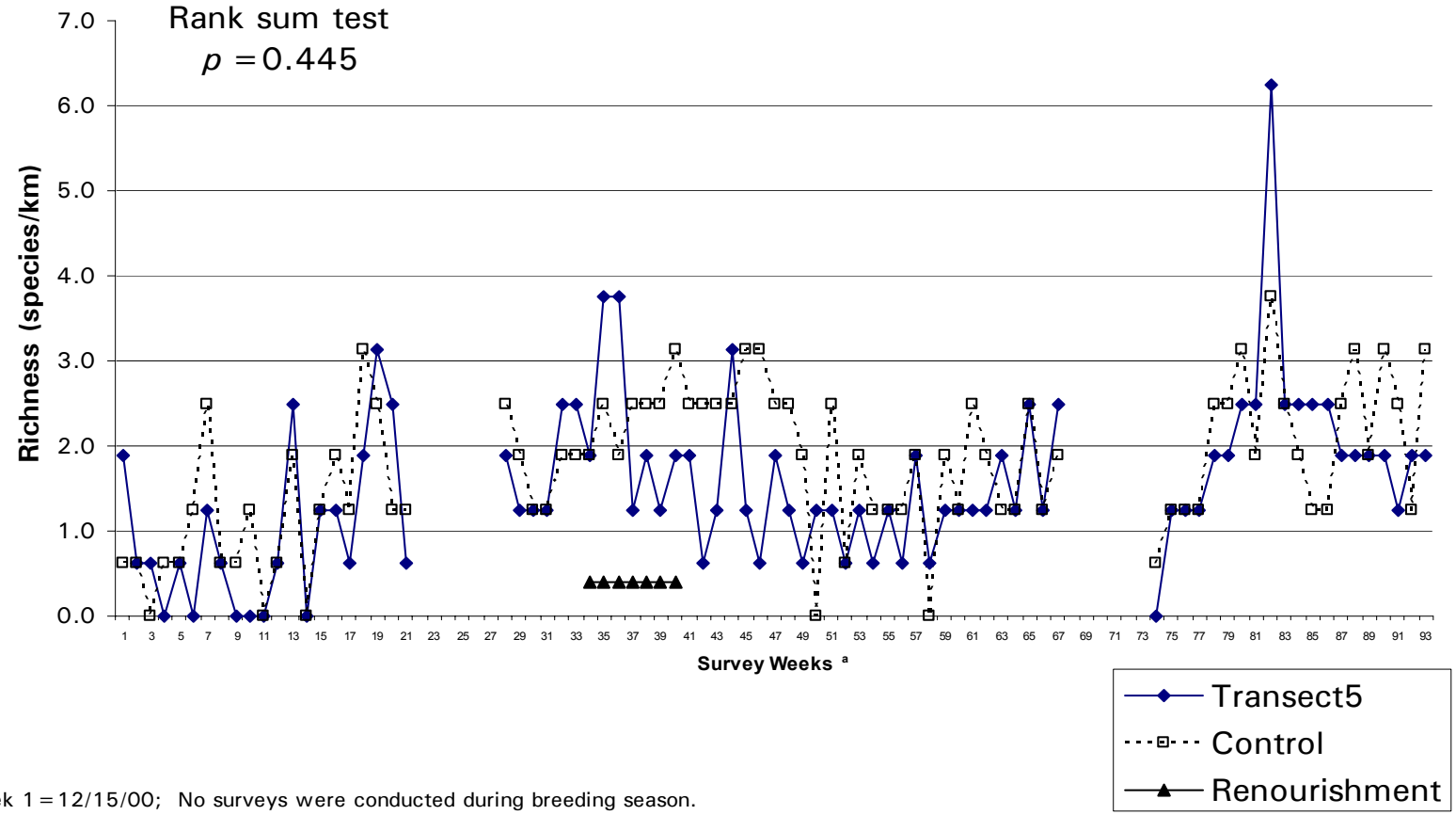
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of shorebird abundance at transect 2 and control



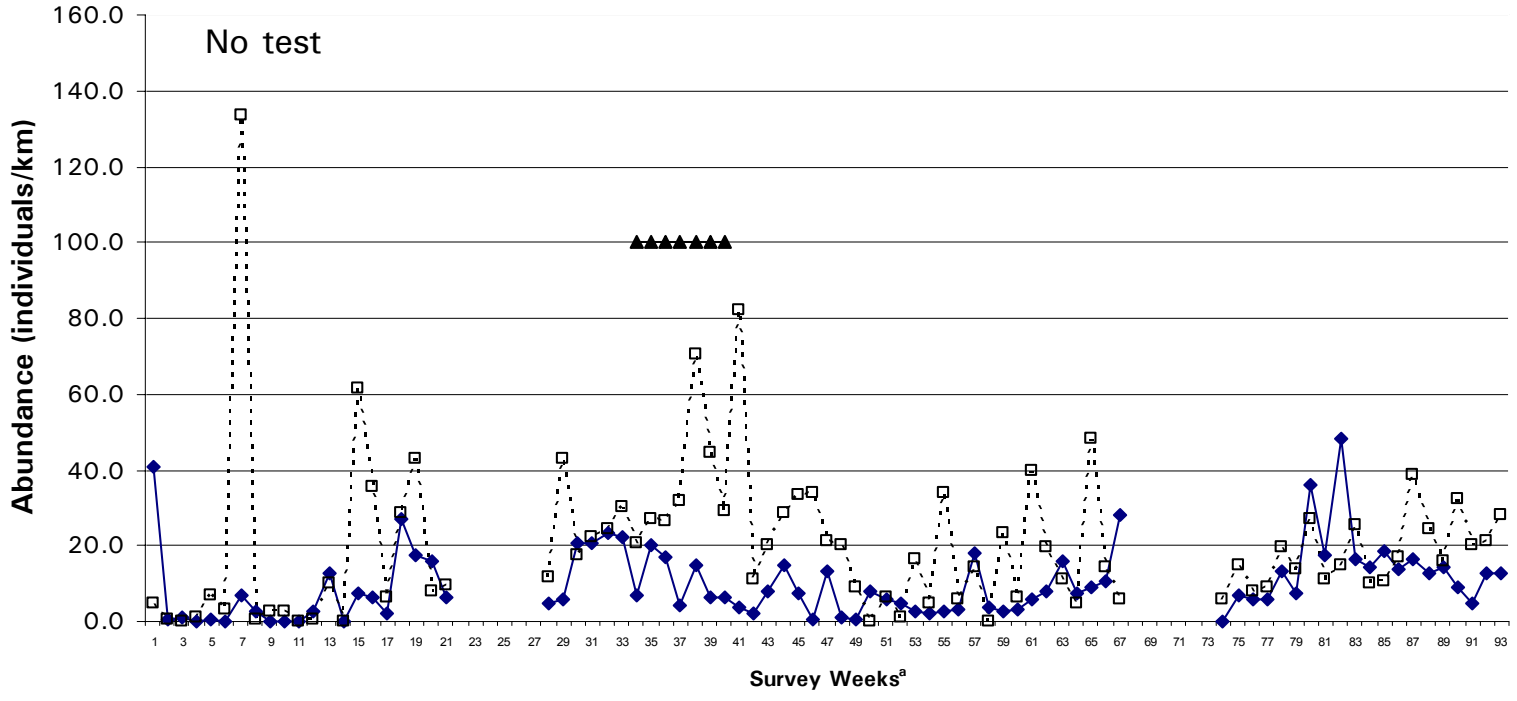
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of shorebird richness at transect 5 and control



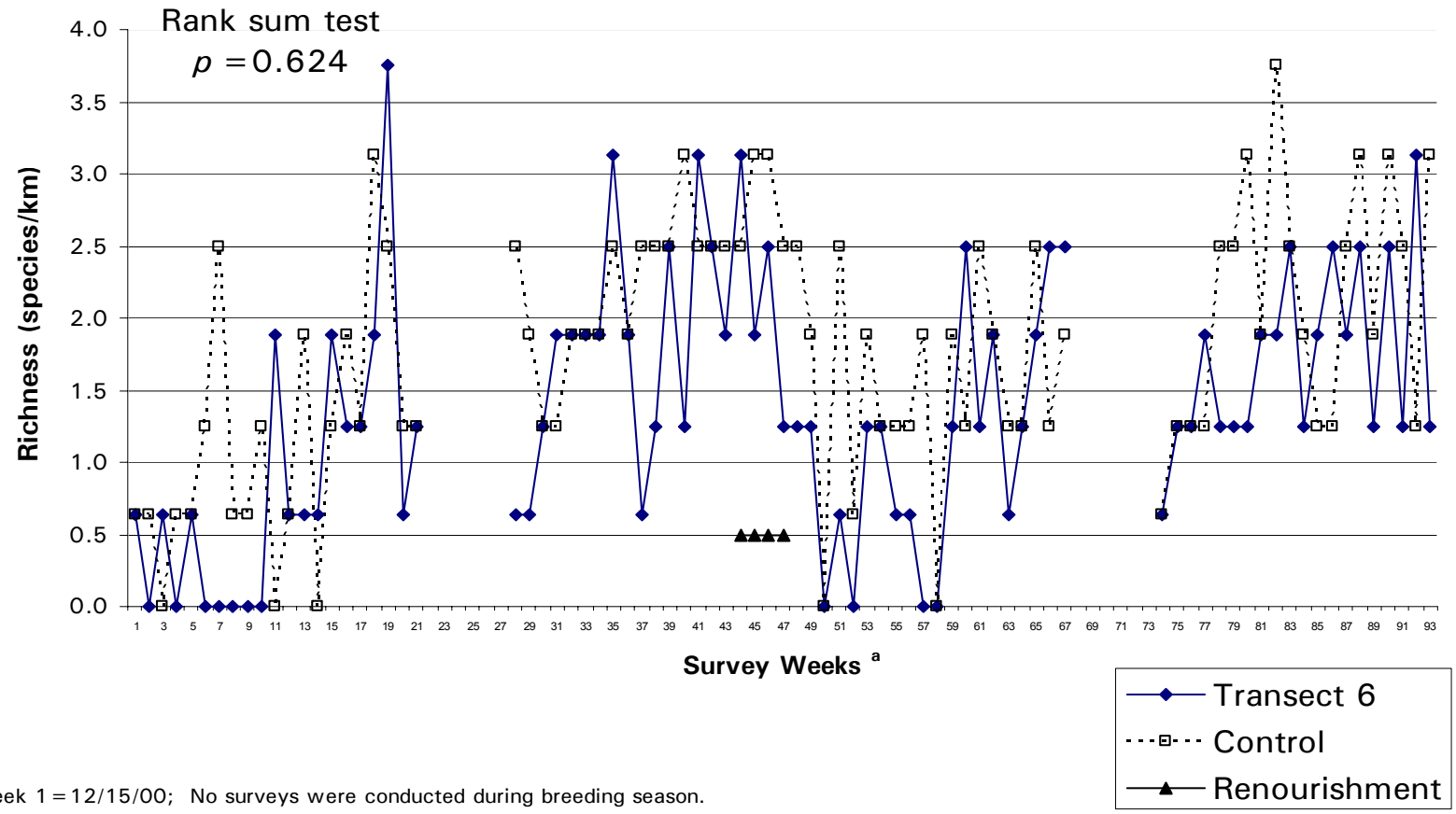
Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of shorebird abundance at transect 5 and control



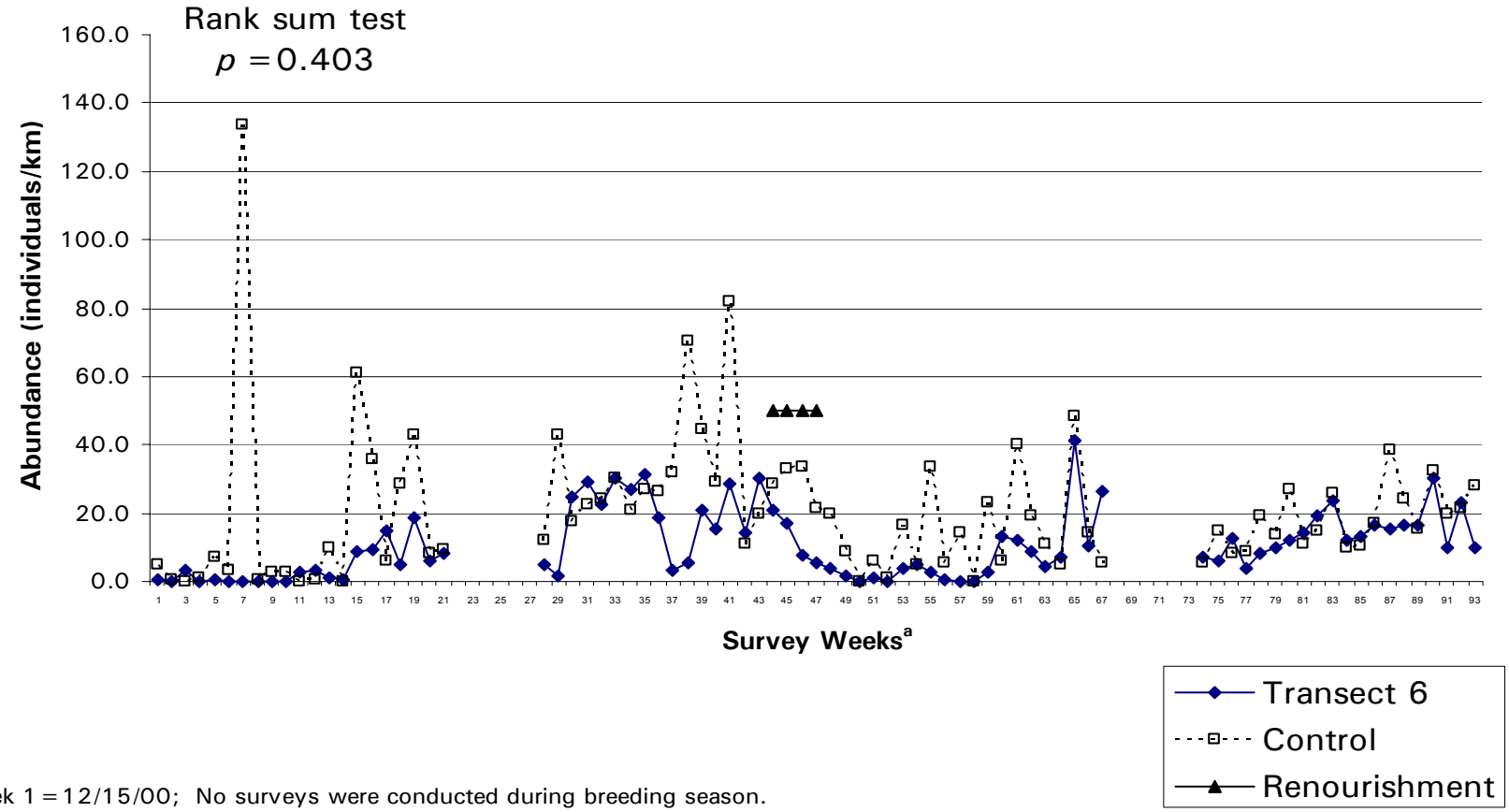
[a] Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of shorebird richness at transect 6 and control



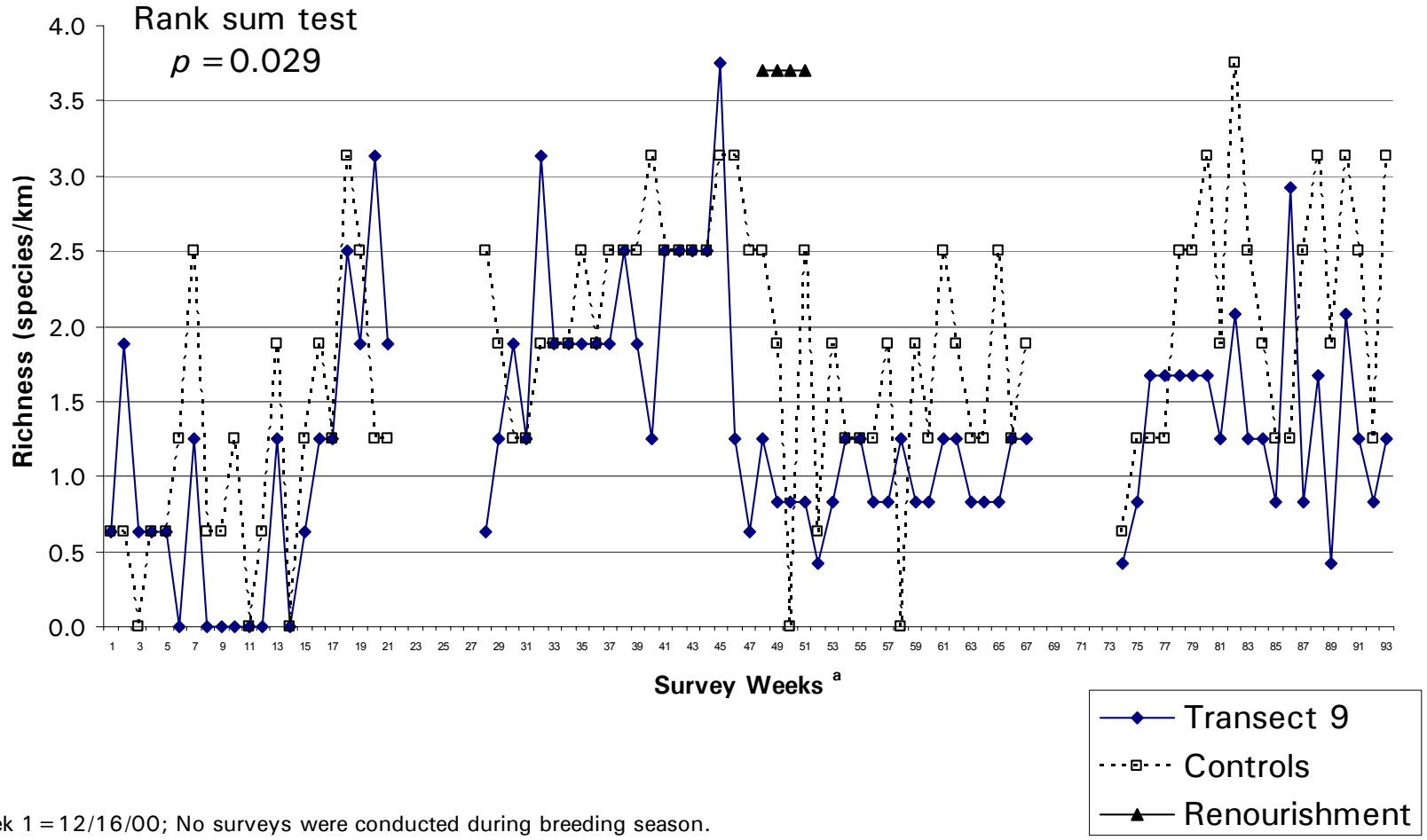
Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of shorebird abundance at transect 6 and control



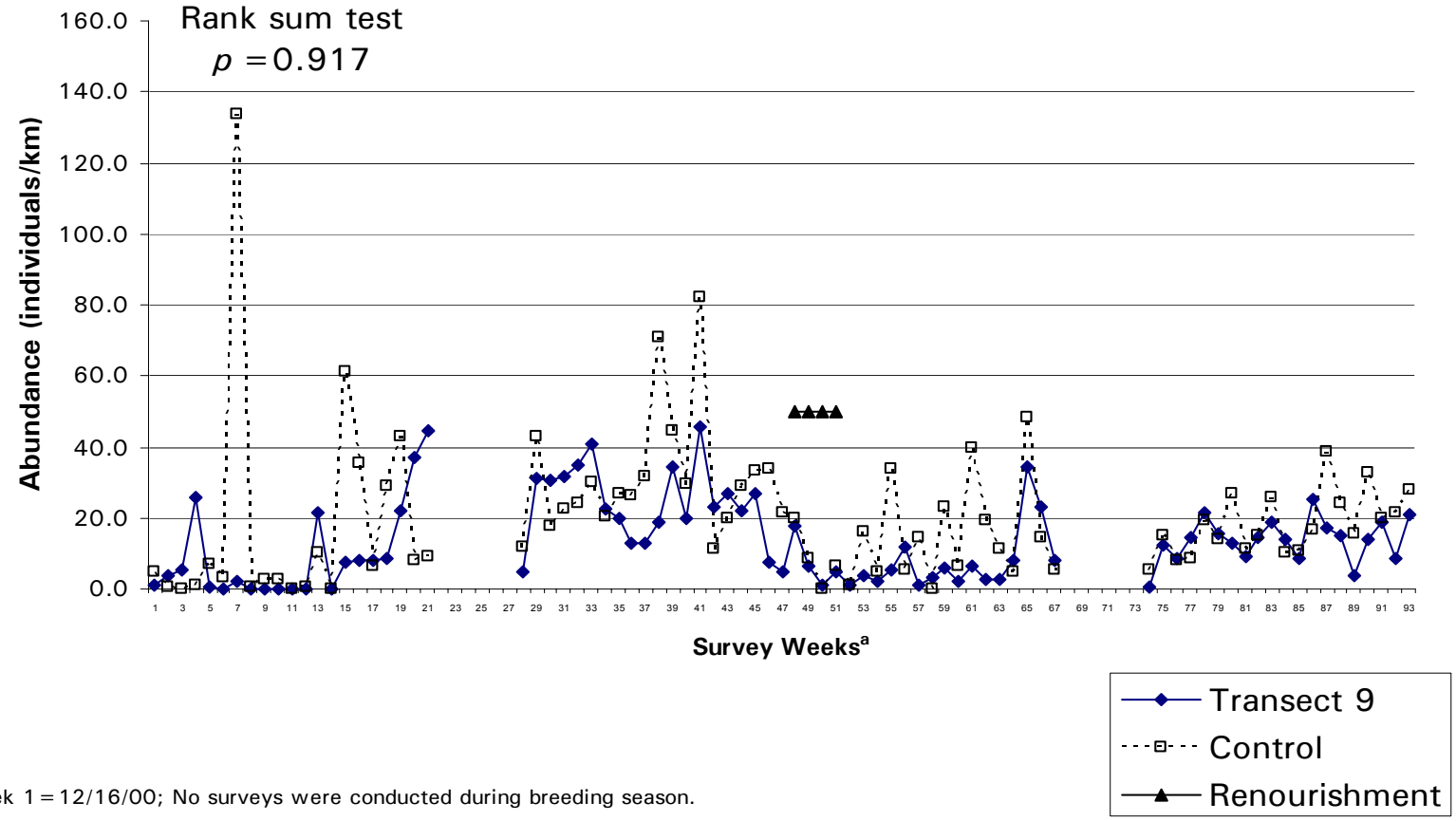
[a] Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of shorebird richness at transect 9 and control



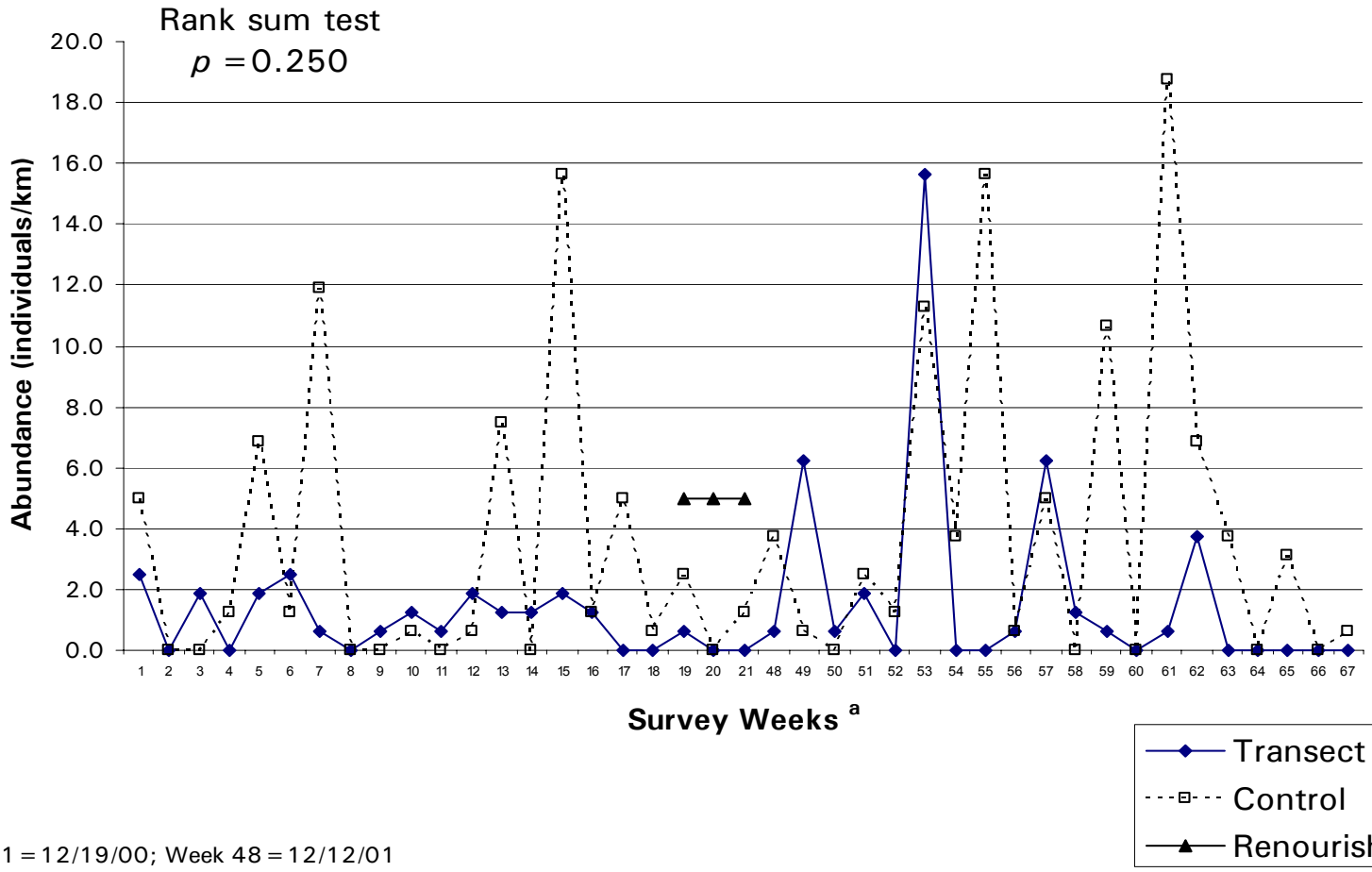
Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of shorebird abundance at transect 9 and control



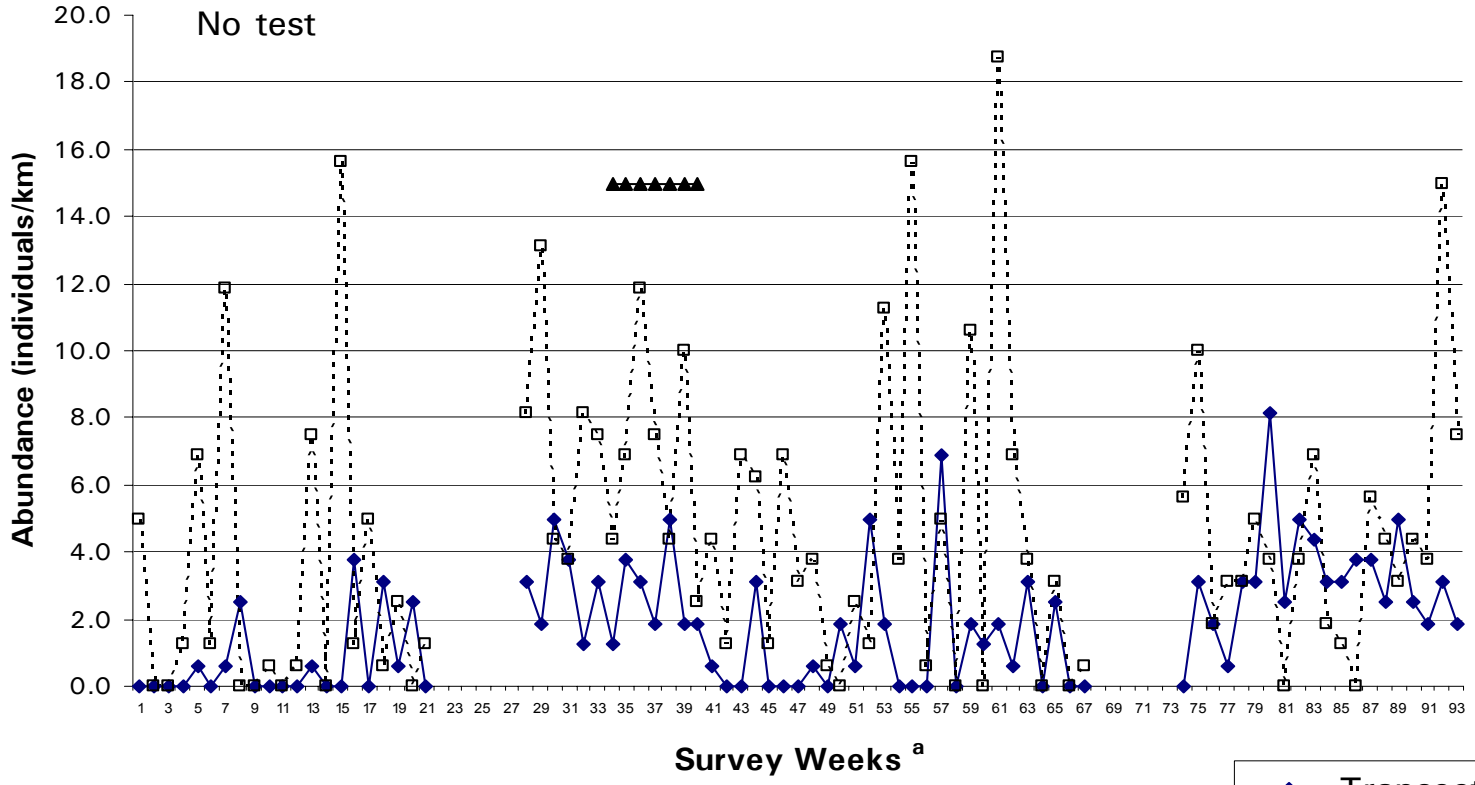
[a] Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of willet abundance at transect 2 and control



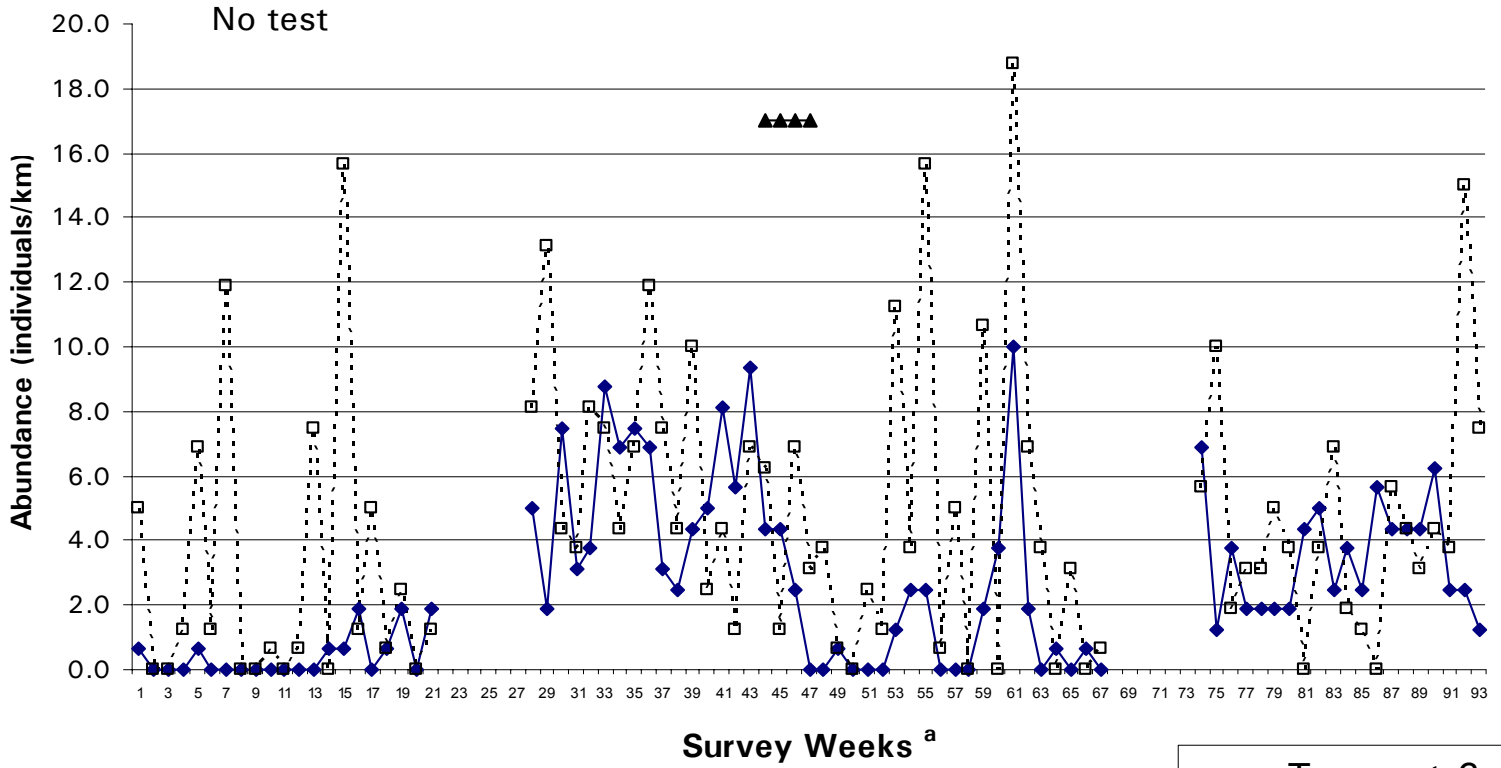
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of willet abundance at transect 5 and control



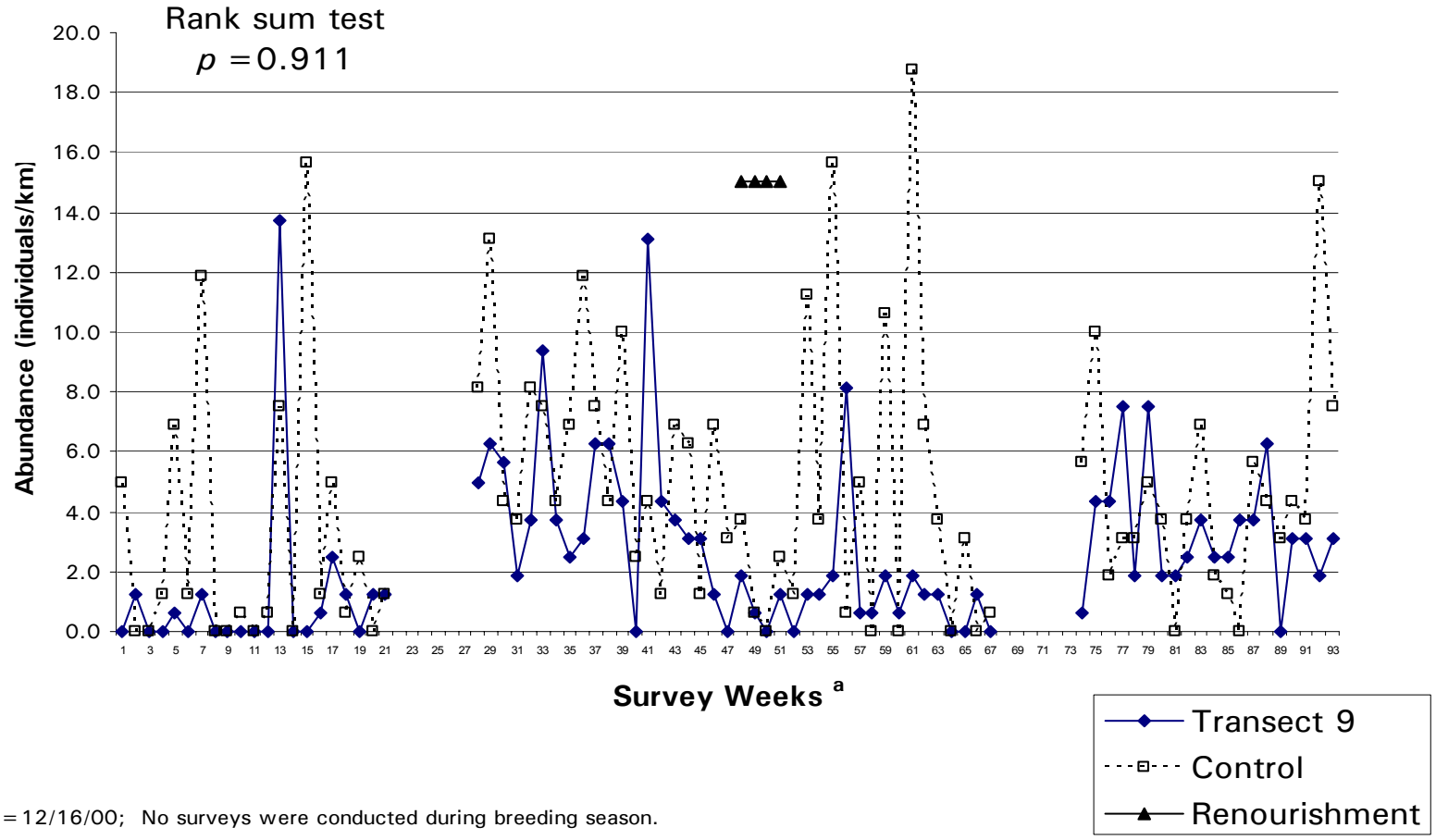
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of willet abundance at transect 6 and control



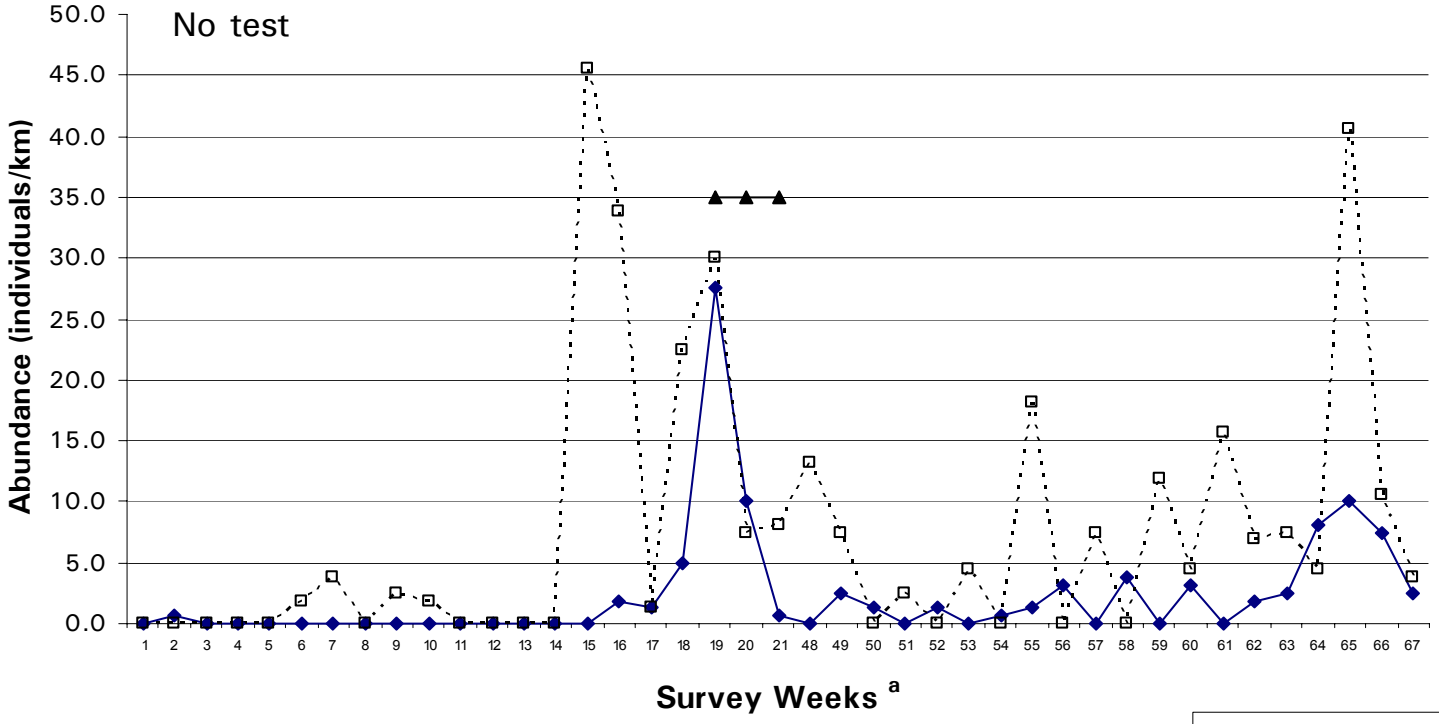
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of willet abundance at transect 9 and control



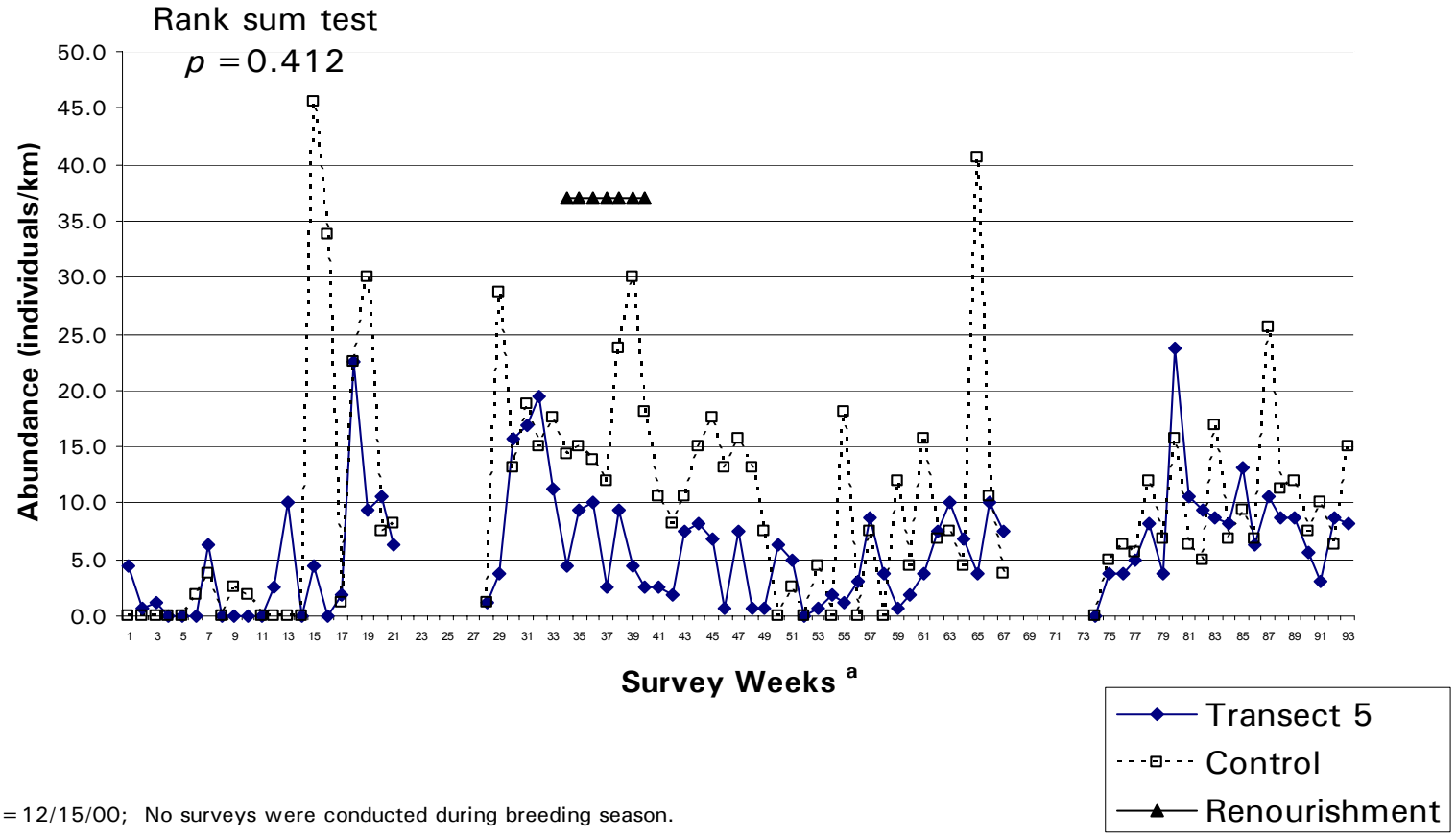
[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of sanderling abundance at transect 2 and control



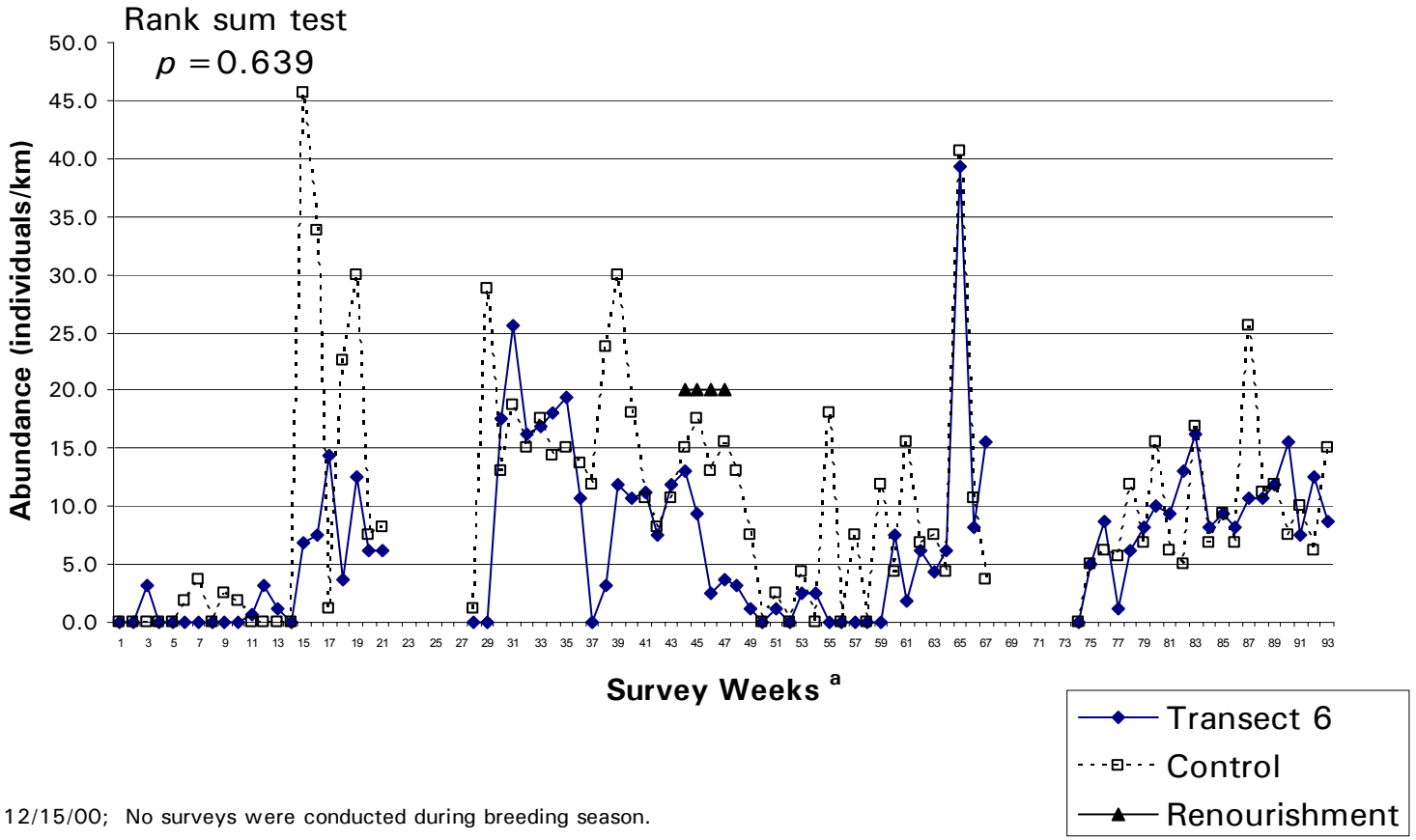
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of sanderling abundance at transect 5 and control



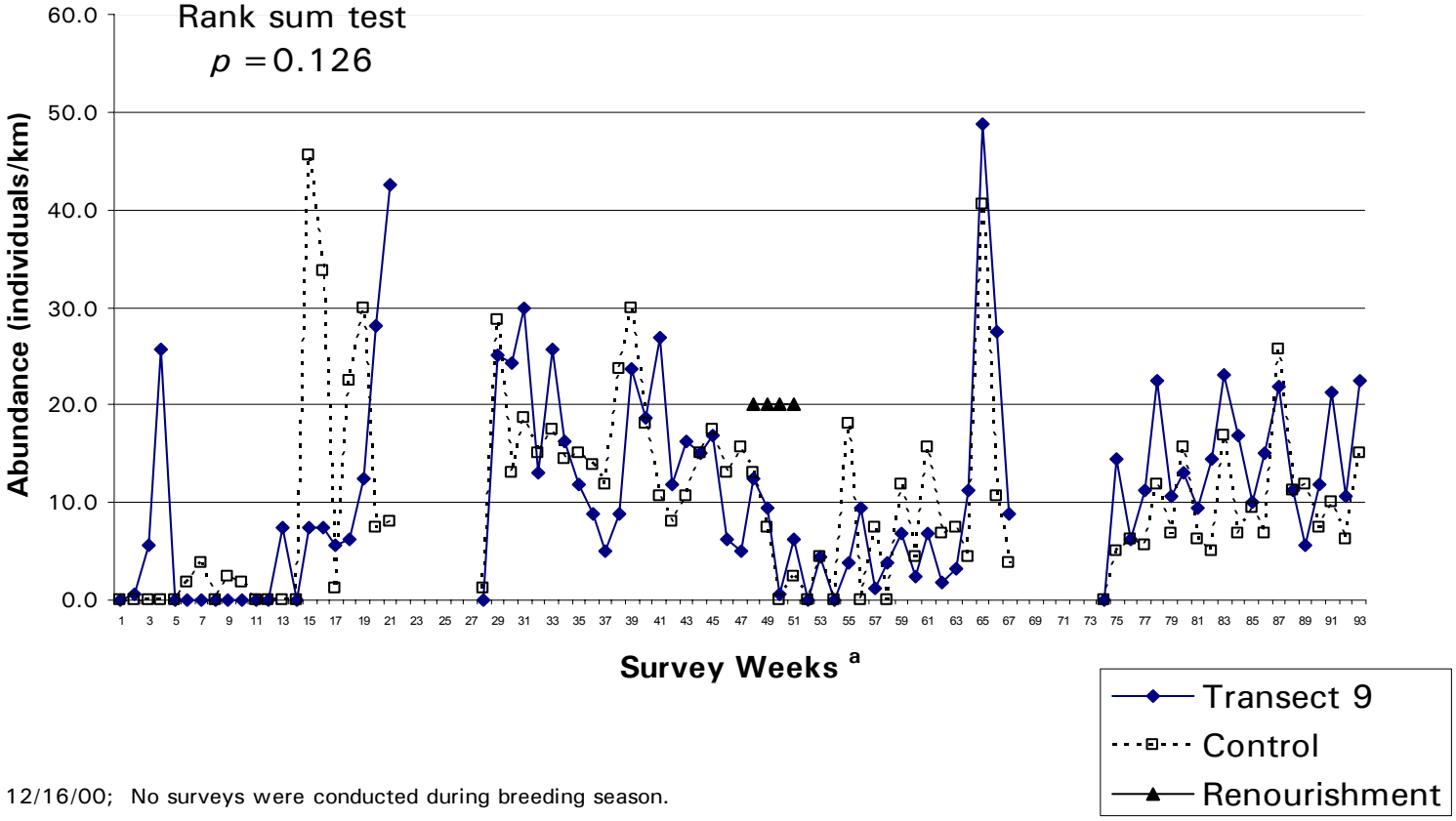
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of sanderling abundance at transect 6 and control



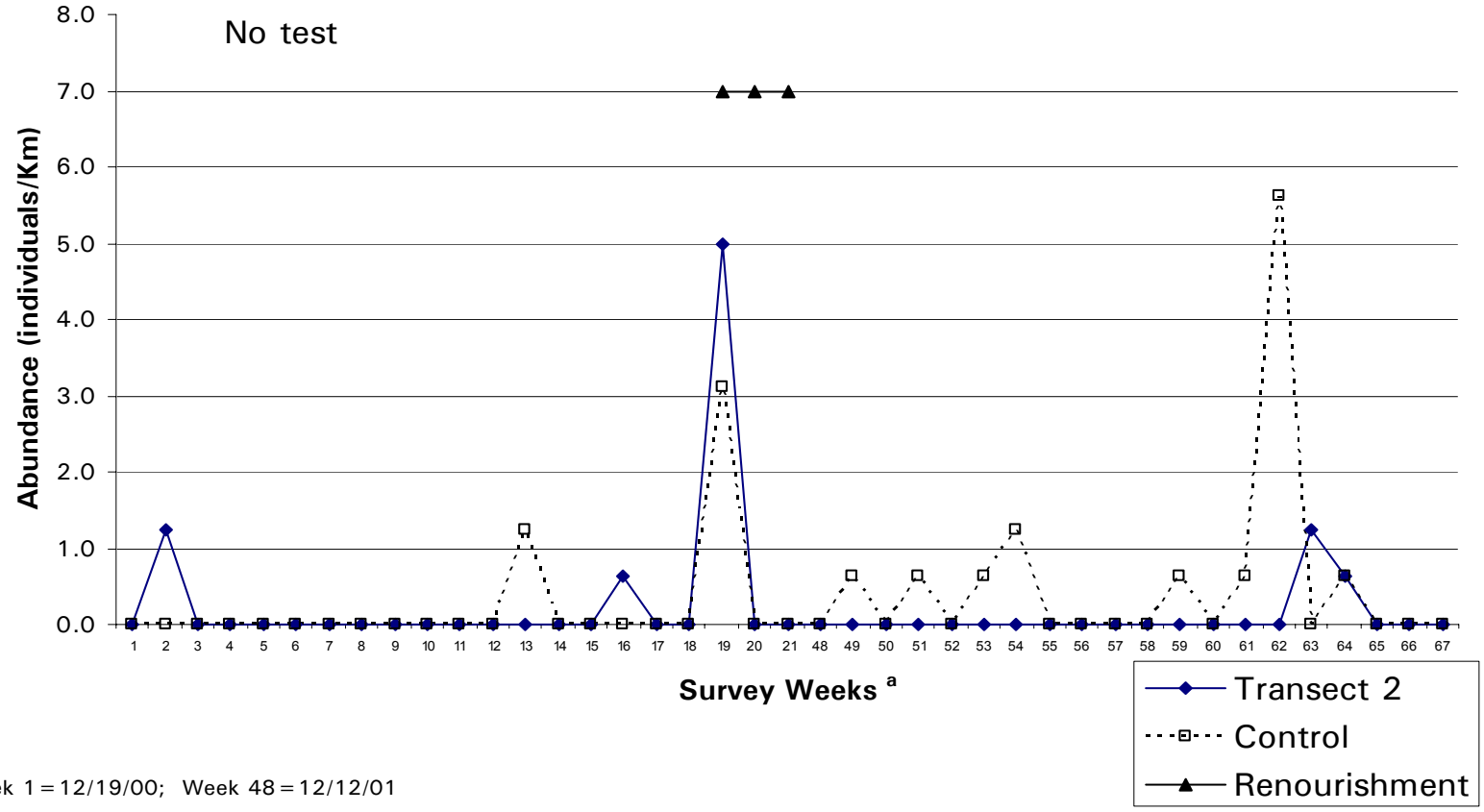
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of sanderling abundance at transect 9 and control



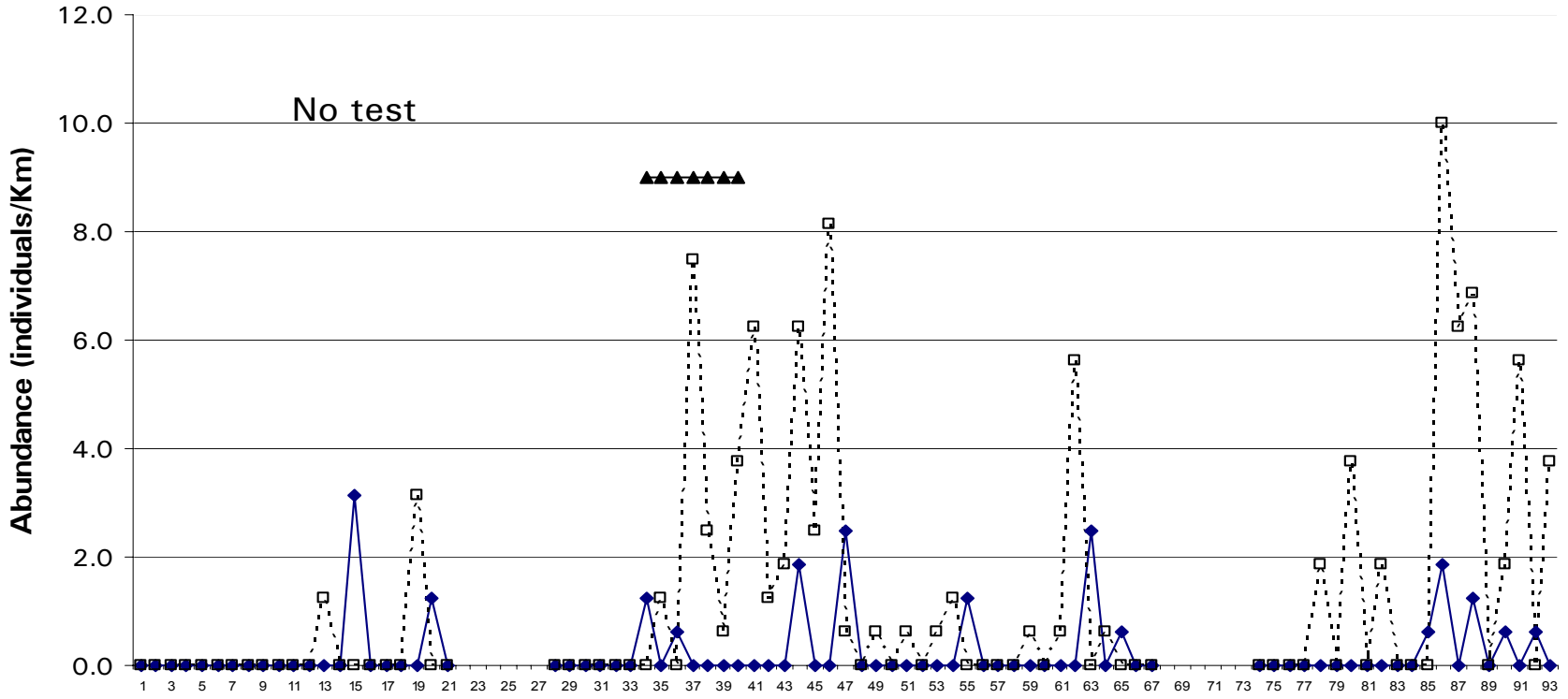
[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of black-bellied plover abundance at transect 2 and control



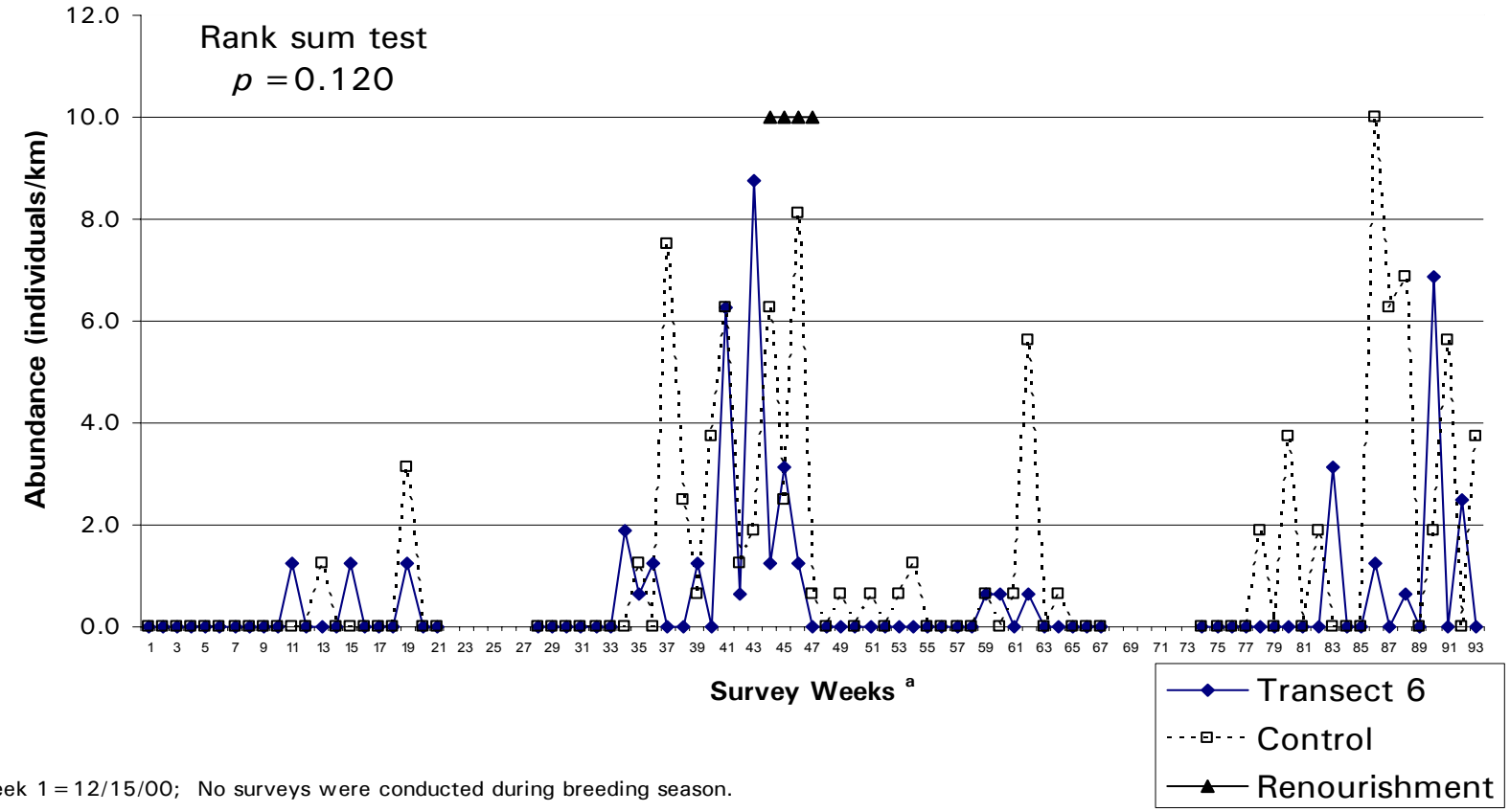
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of black-bellied plover abundance at transect 5 and control



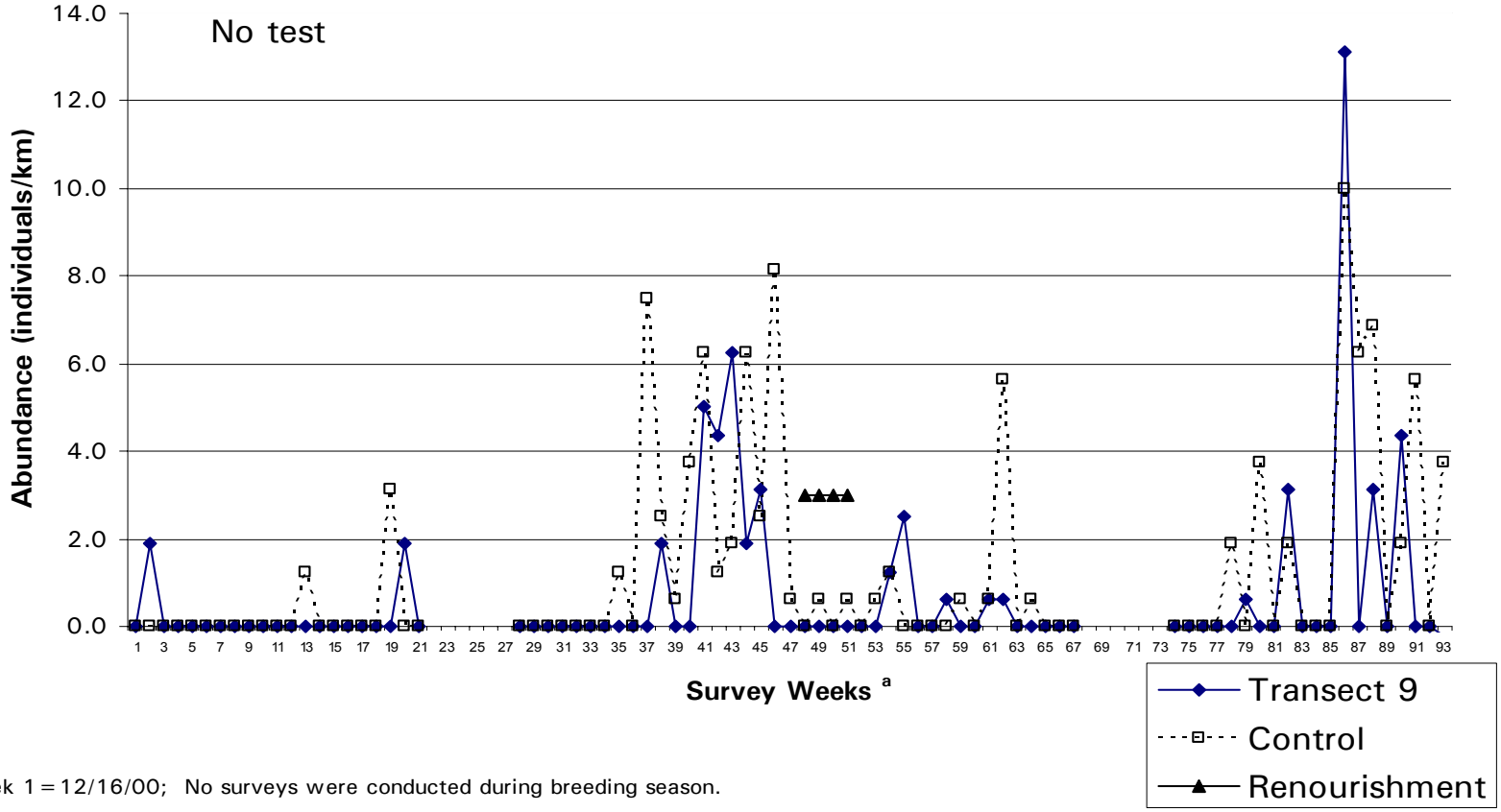
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of black-bellied plover abundance at transect 6 and control



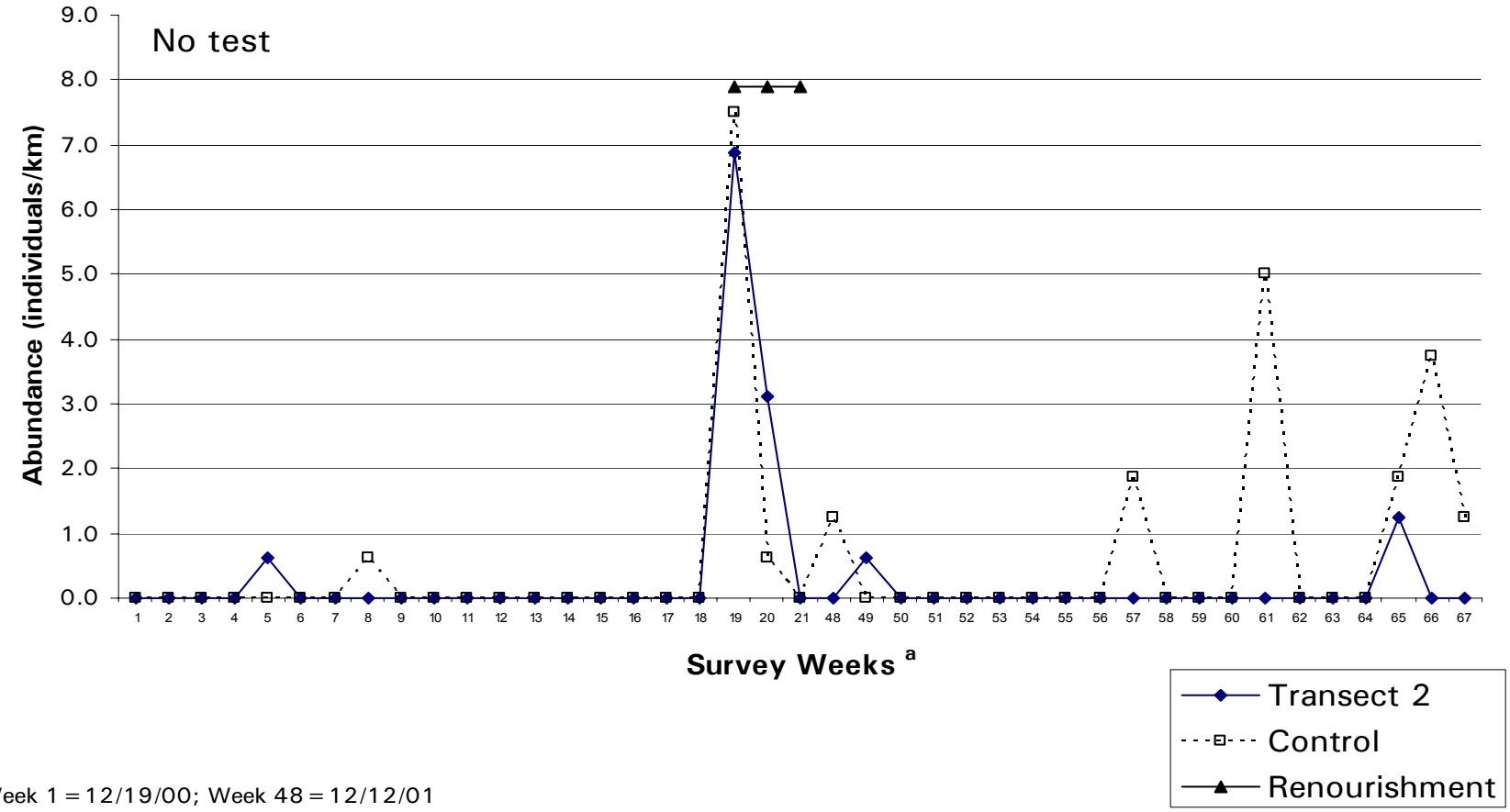
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of black-bellied plover abundance at transect 9 and control



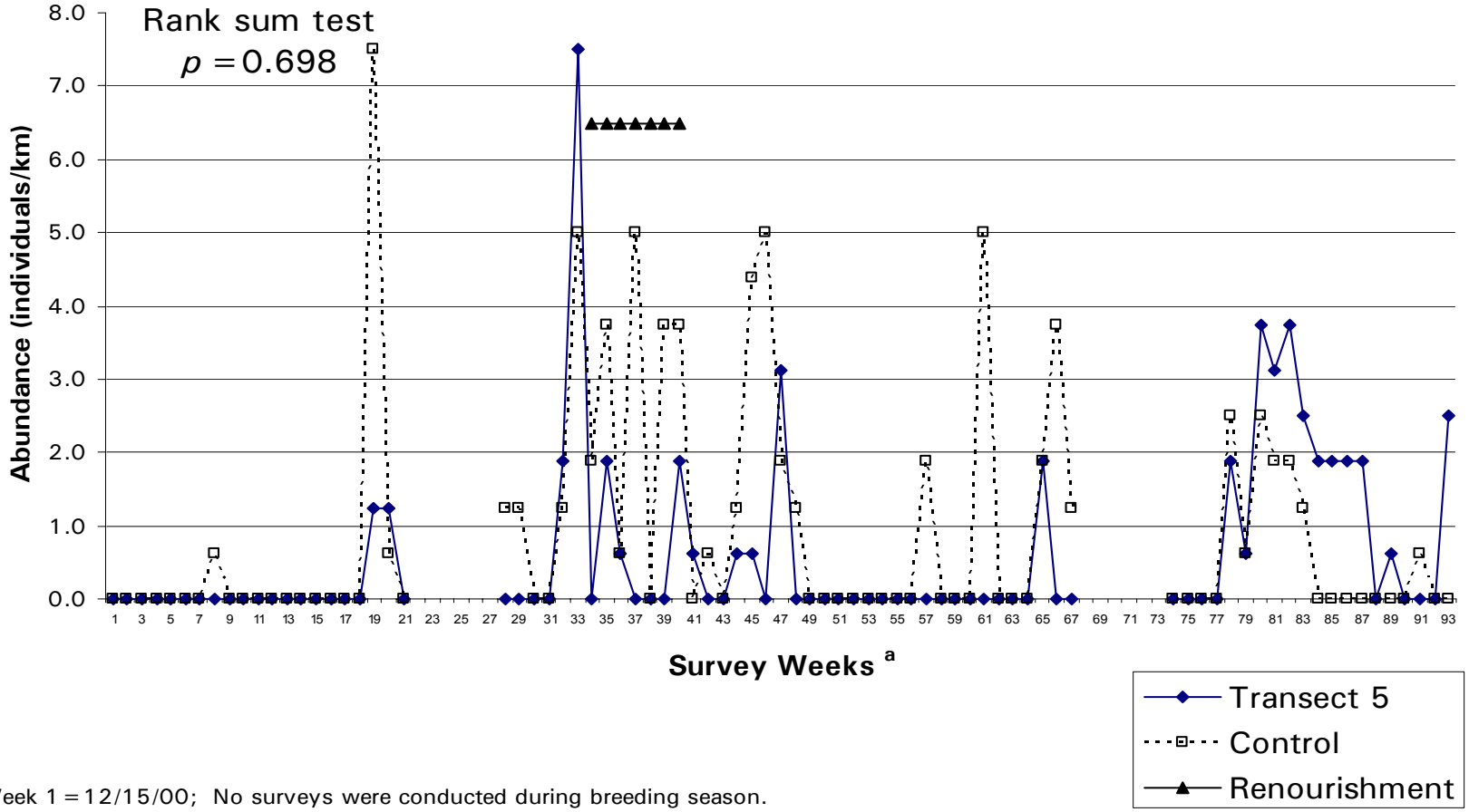
[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.

Weekly comparison of ruddy turnstone abundance at transect 2 and control



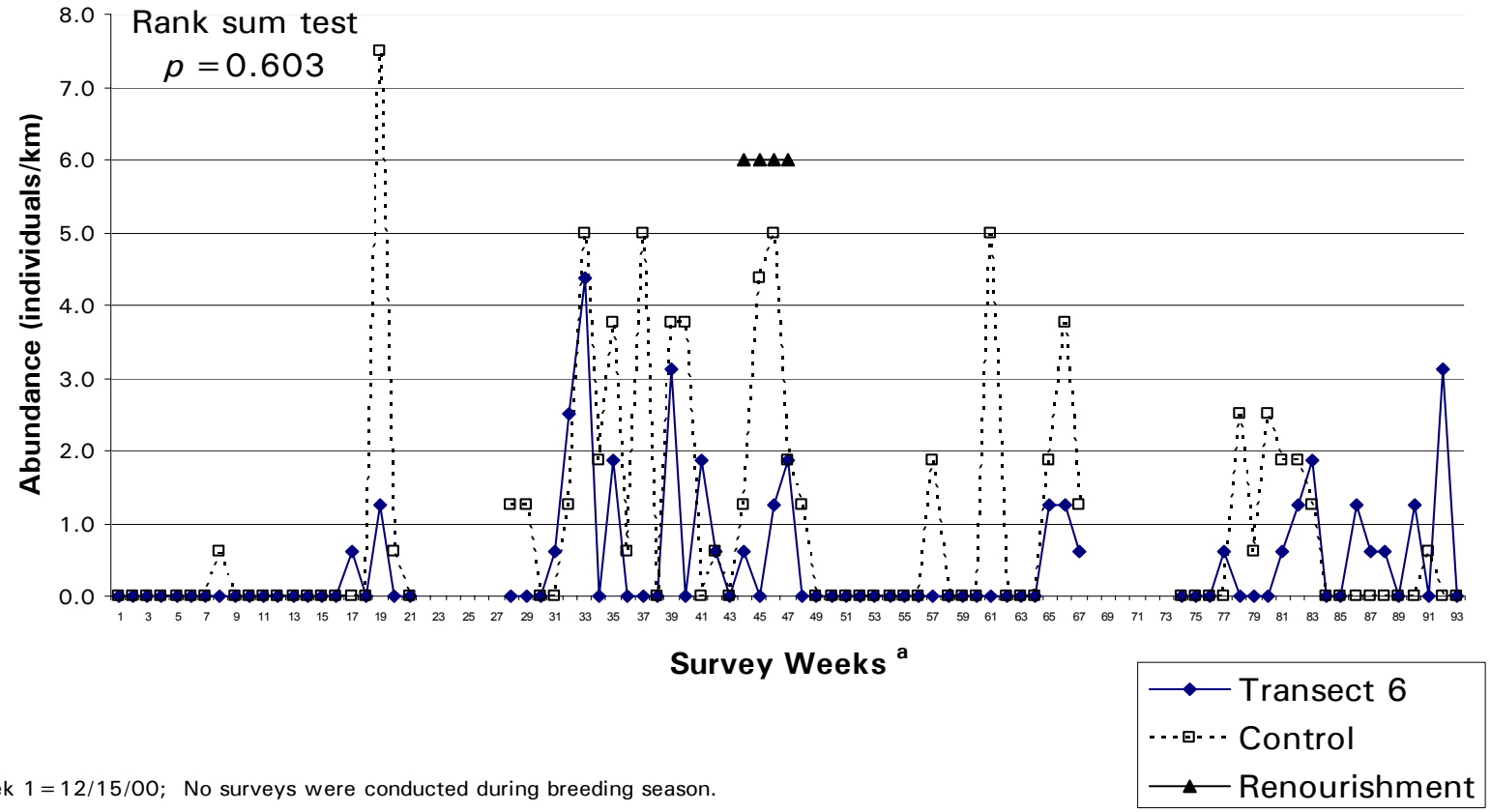
[a]Week 1 = 12/19/00; Week 48 = 12/12/01

Weekly comparison of ruddy turnstone abundance at transect 5 and control



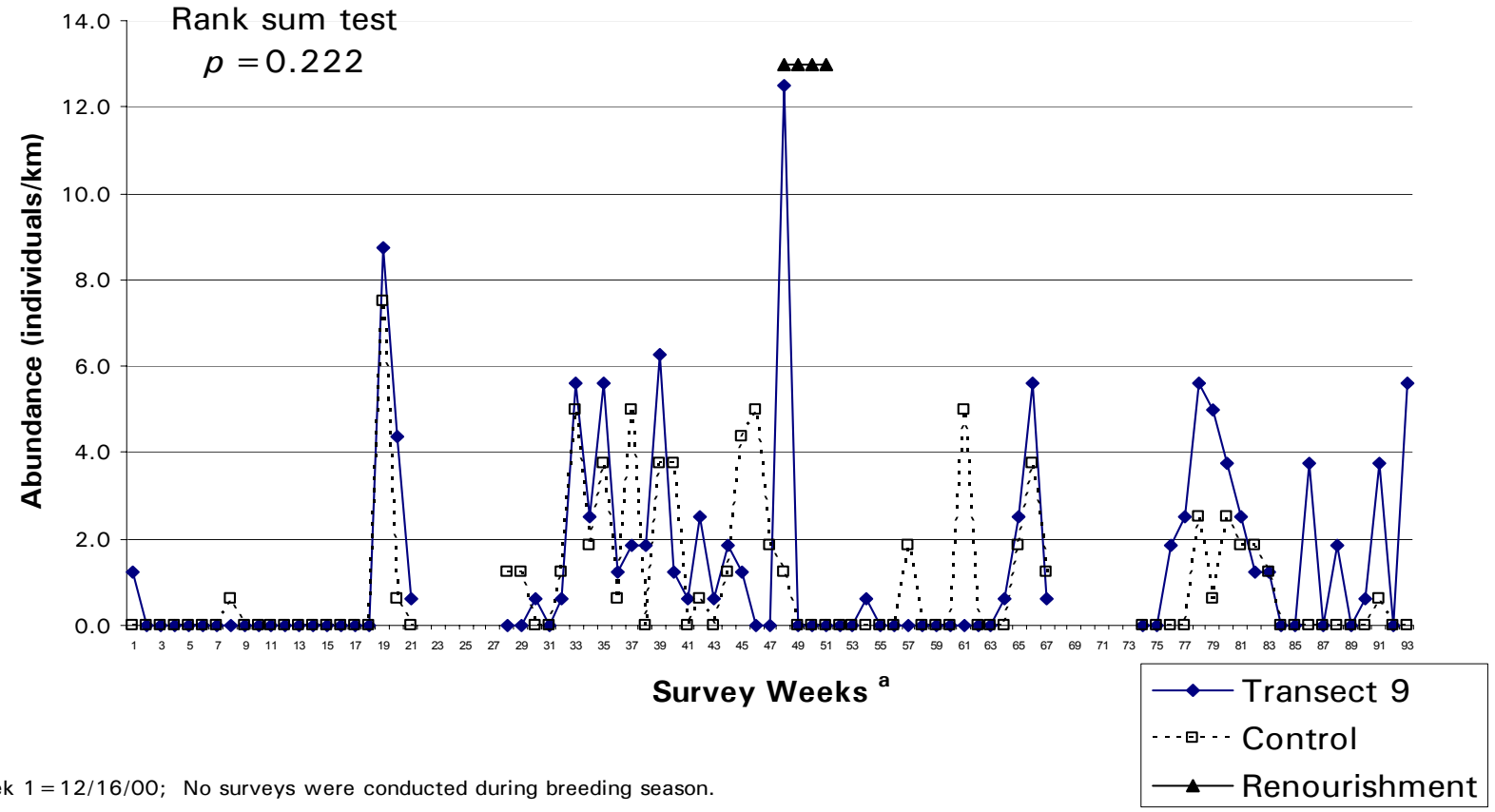
[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of ruddy turnstone abundance at transect 6 and control



[a]Week 1 = 12/15/00; No surveys were conducted during breeding season.

Weekly comparison of ruddy turnstone abundance at transect 9 and control



[a]Week 1 = 12/16/00; No surveys were conducted during breeding season.